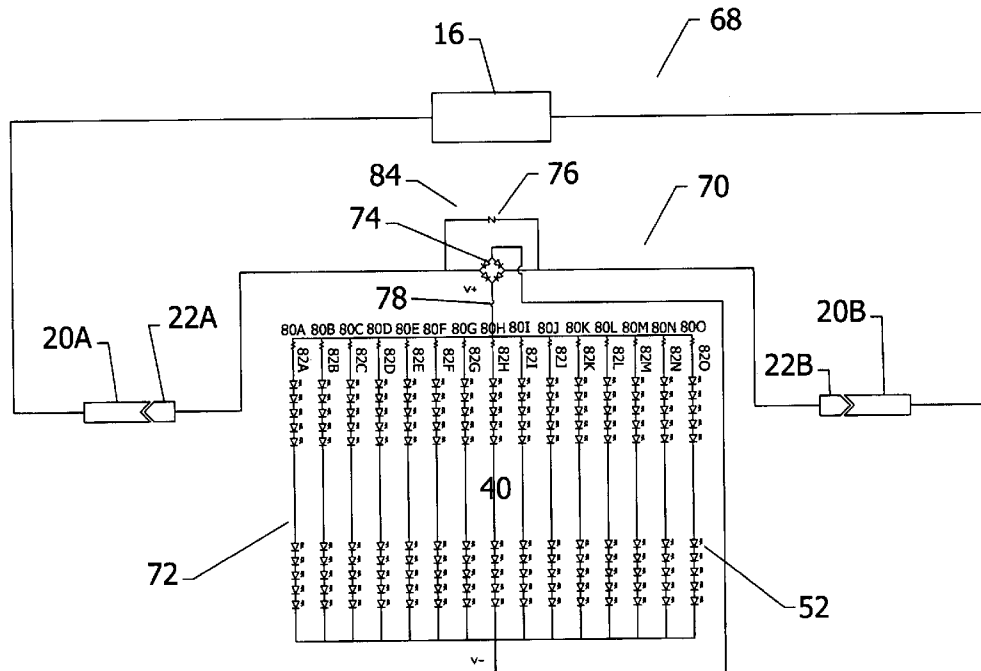




US 20050162101A1

(19) **United States**(12) **Patent Application Publication****Leong et al.**(10) **Pub. No.: US 2005/0162101 A1**(43) **Pub. Date: Jul. 28, 2005**(54) **POWER CONTROLS FOR TUBE MOUNTED
LEDS WITH BALLAST**(75) Inventors: **Susan J. Leong**, New York, NY (US);
John Kit, Brooklyn, NY (US)Correspondence Address:
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145 East 15th Street #10R
New York, NY 10003 (US)(73) Assignee: **DeNovo Lighting, LLC**, Brooklyn, NY(21) Appl. No.: **11/052,328**(22) Filed: **Feb. 7, 2005****Related U.S. Application Data**(63) Continuation-in-part of application No. 10/822,579,
filed on Apr. 12, 2004, now Pat. No. 6,853,151, which
is a continuation-in-part of application No. 10/299,
870, filed on Nov. 19, 2002, now Pat. No. 6,762,562.**Publication Classification**(51) **Int. Cl.⁷ H05B 37/00**(52) **U.S. Cl. 315/291; 315/312; 315/200 A**(57) **ABSTRACT**

A power saving device for a light emitting diode (LED) lamp mounted to an existing fixture for a fluorescent lamp having a ballast assembly and LEDs positioned within a tube and electrical power delivered from the ballast assembly to the LEDs. The LED lamp includes means for controlling the delivery of the electrical power from the ballast assembly to the LEDs wherein the use of electrical power can be reduced or eliminated automatically during periods of non-use. Such means for controlling can include an on-off switch mounted in the tube or can also include a current driver dimmer mounted in the tube that regulates the amount of power delivered to the LEDs. A computer or logic arrays control the dimmer or power switch. A sensor such as an occupancy motion detection sensor mounted external to the tube or within the tube can send signals to the computer or logic array to trigger a switch or control a dimmer. Two or more such LED lamps with one or more computers or logic arrays in network communication with sensors can be controlled, so as to reduce flickering between lamps when illumination areas are being alternately occupied. Preset or manually set timers can control switches or be used in combination with the computer, logic array, and dimmer.



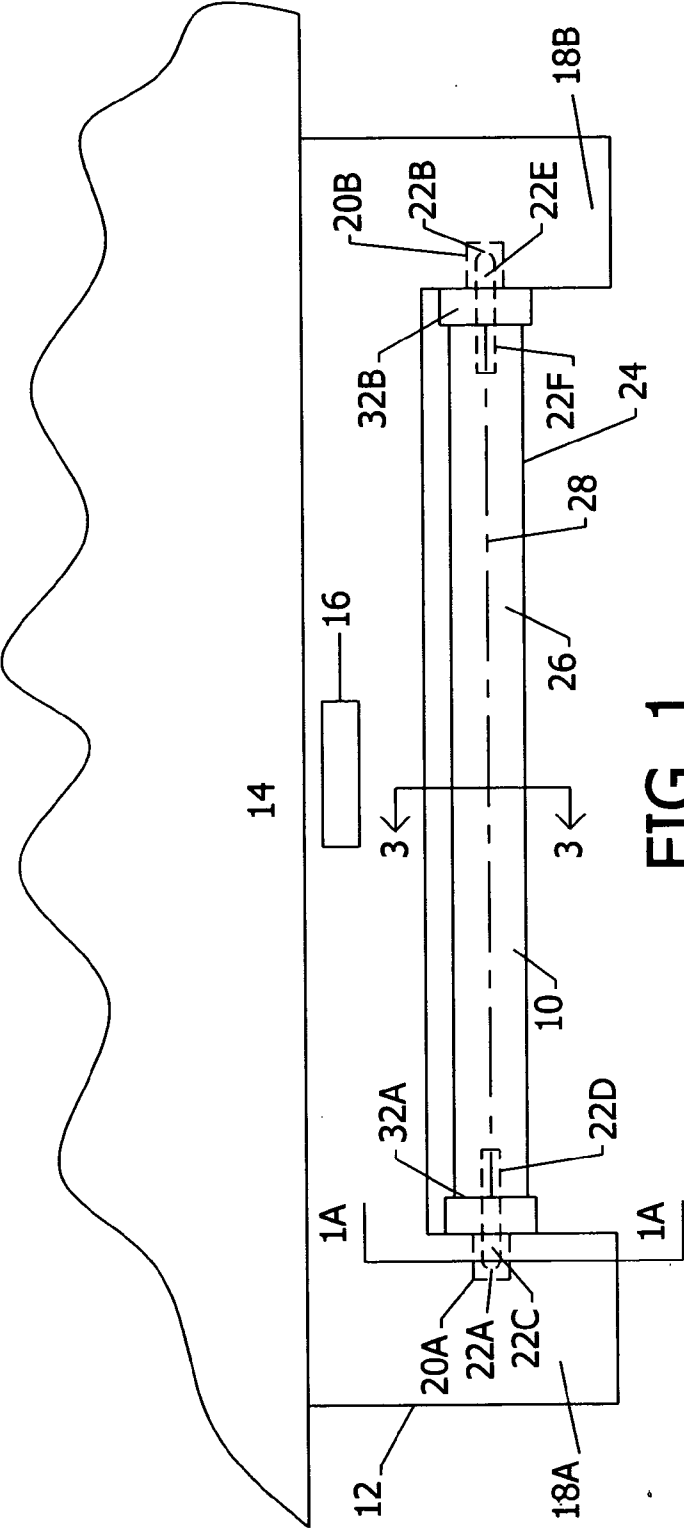


FIG. 1

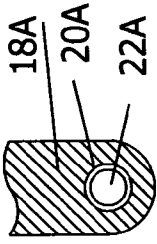
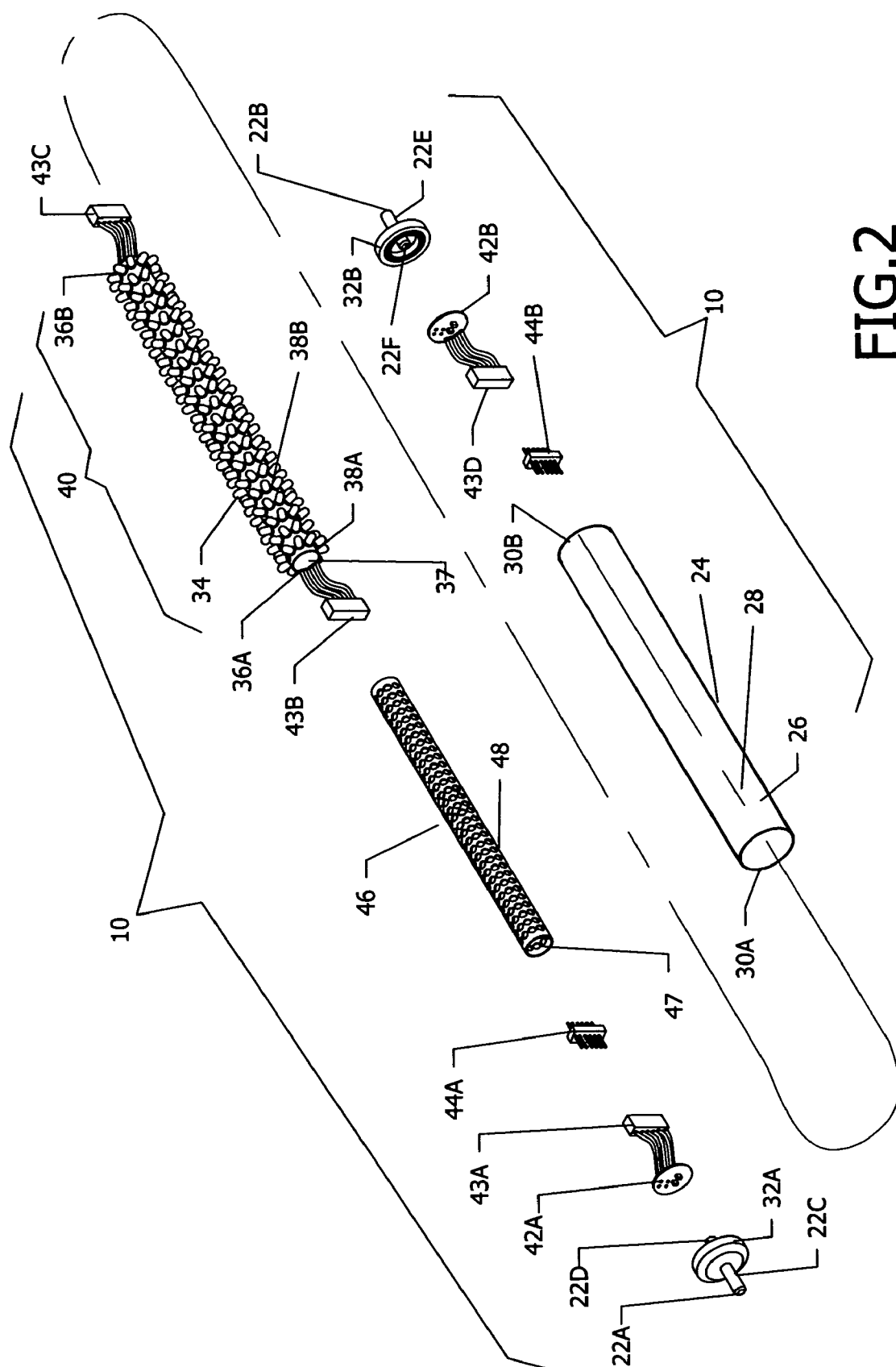


FIG. 1A



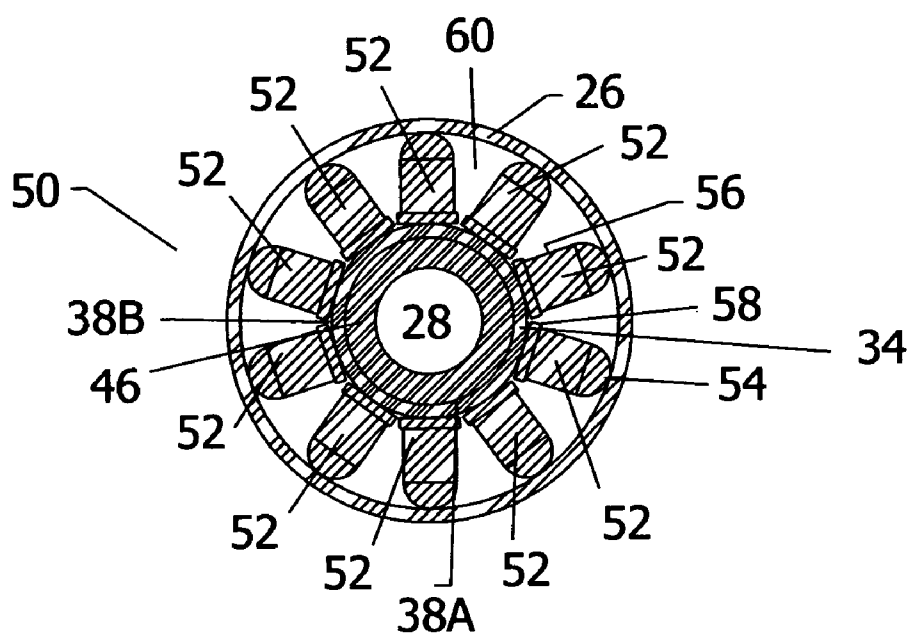


FIG. 3

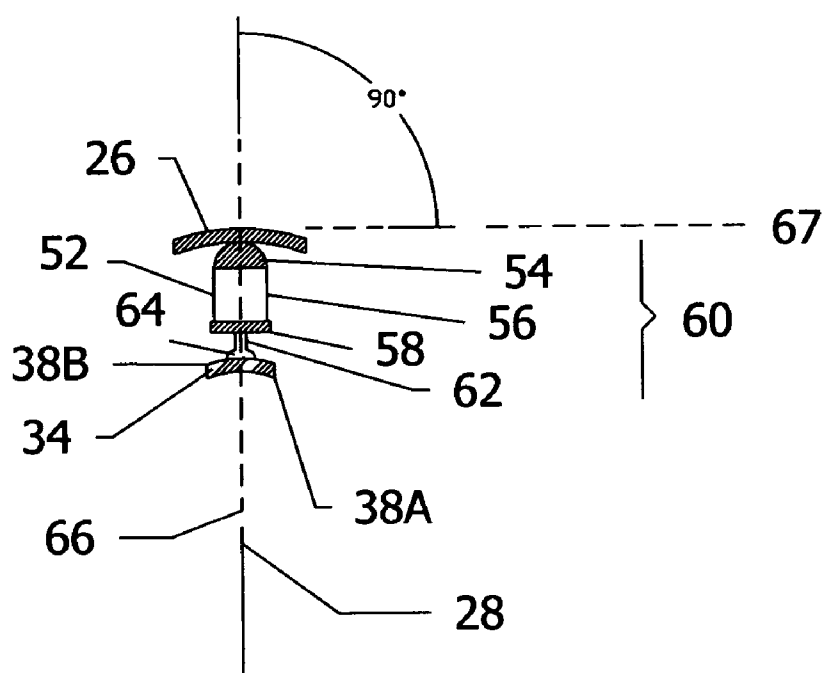


FIG. 3A

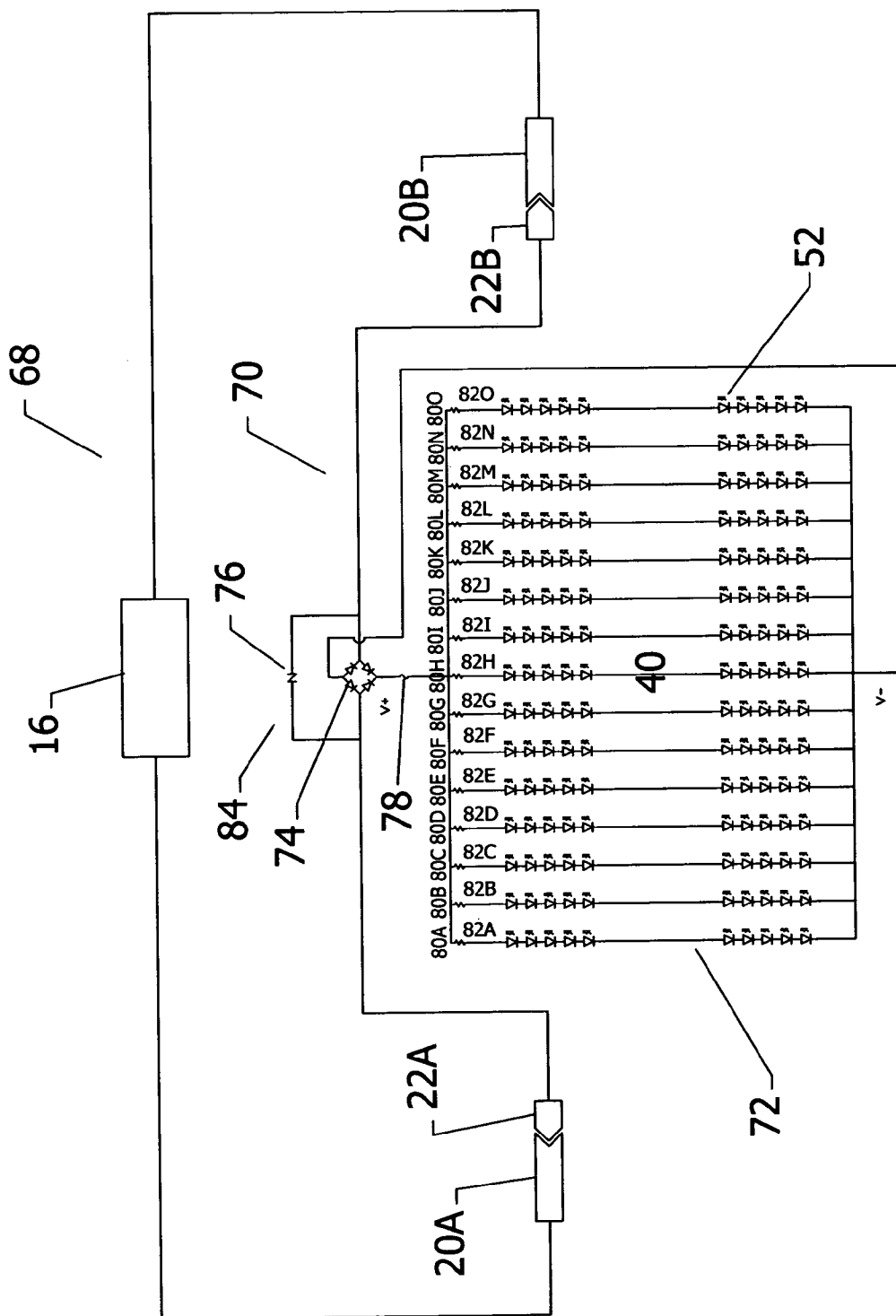


FIG. 4

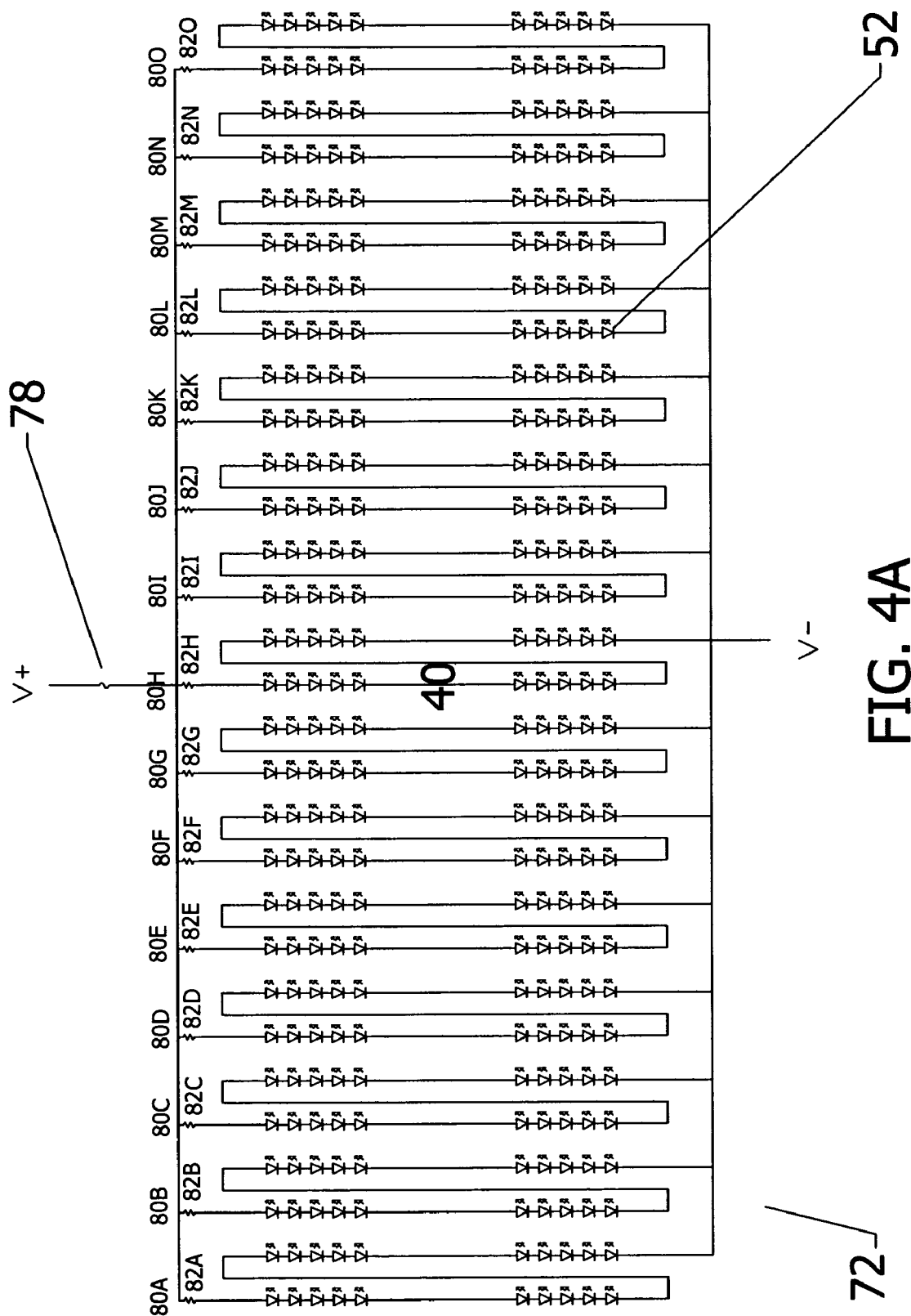


FIG. 4A

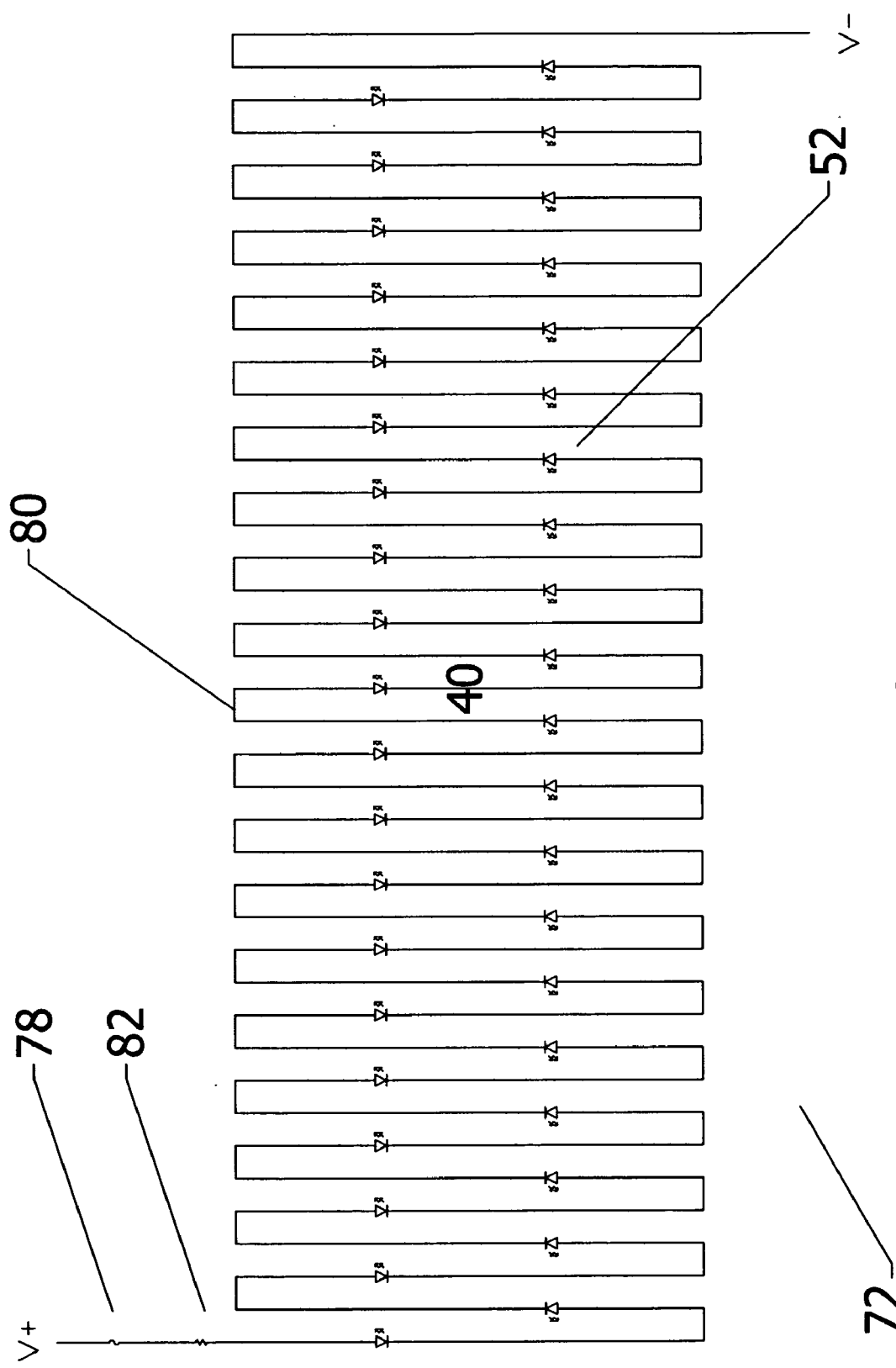


FIG. 4B

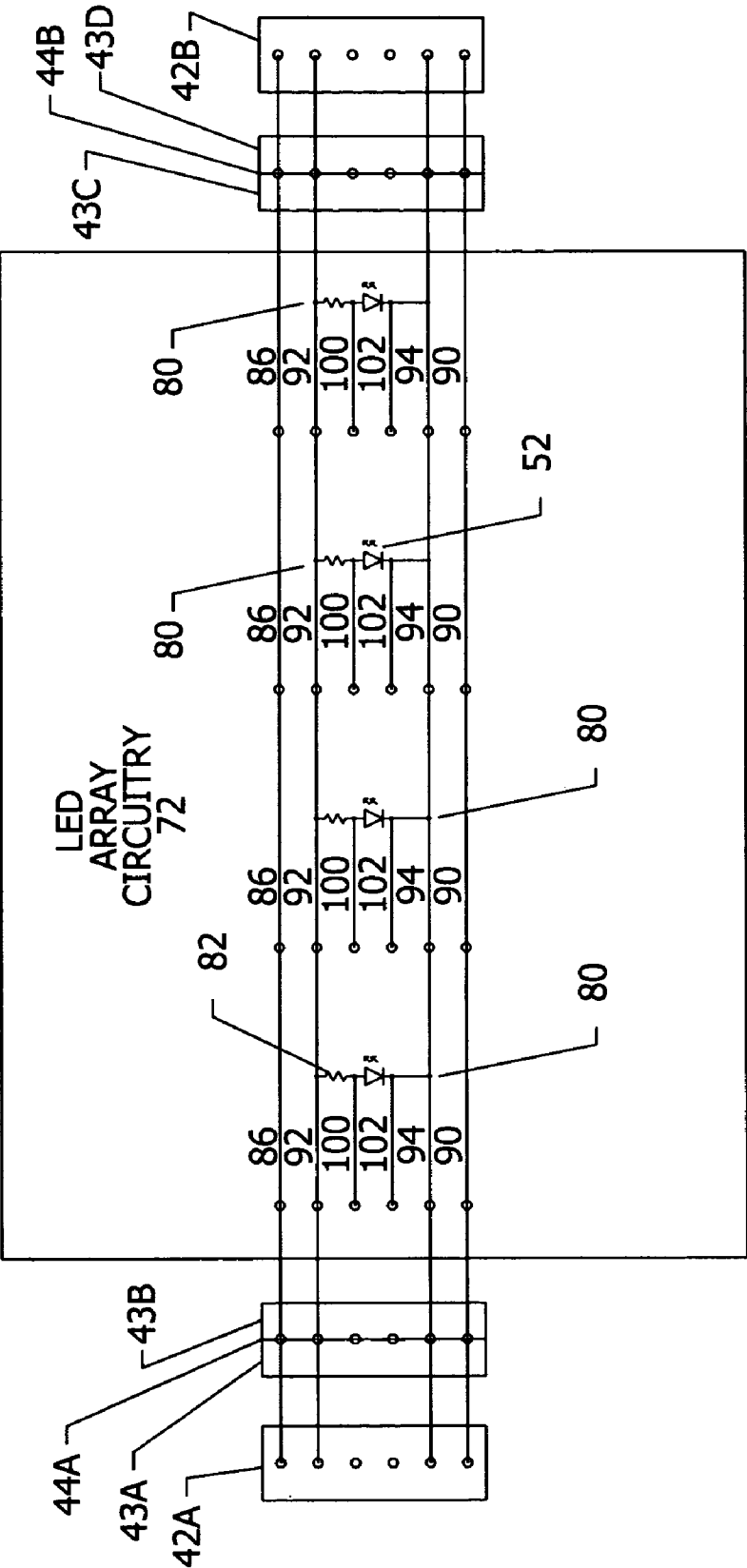


FIG. 4C

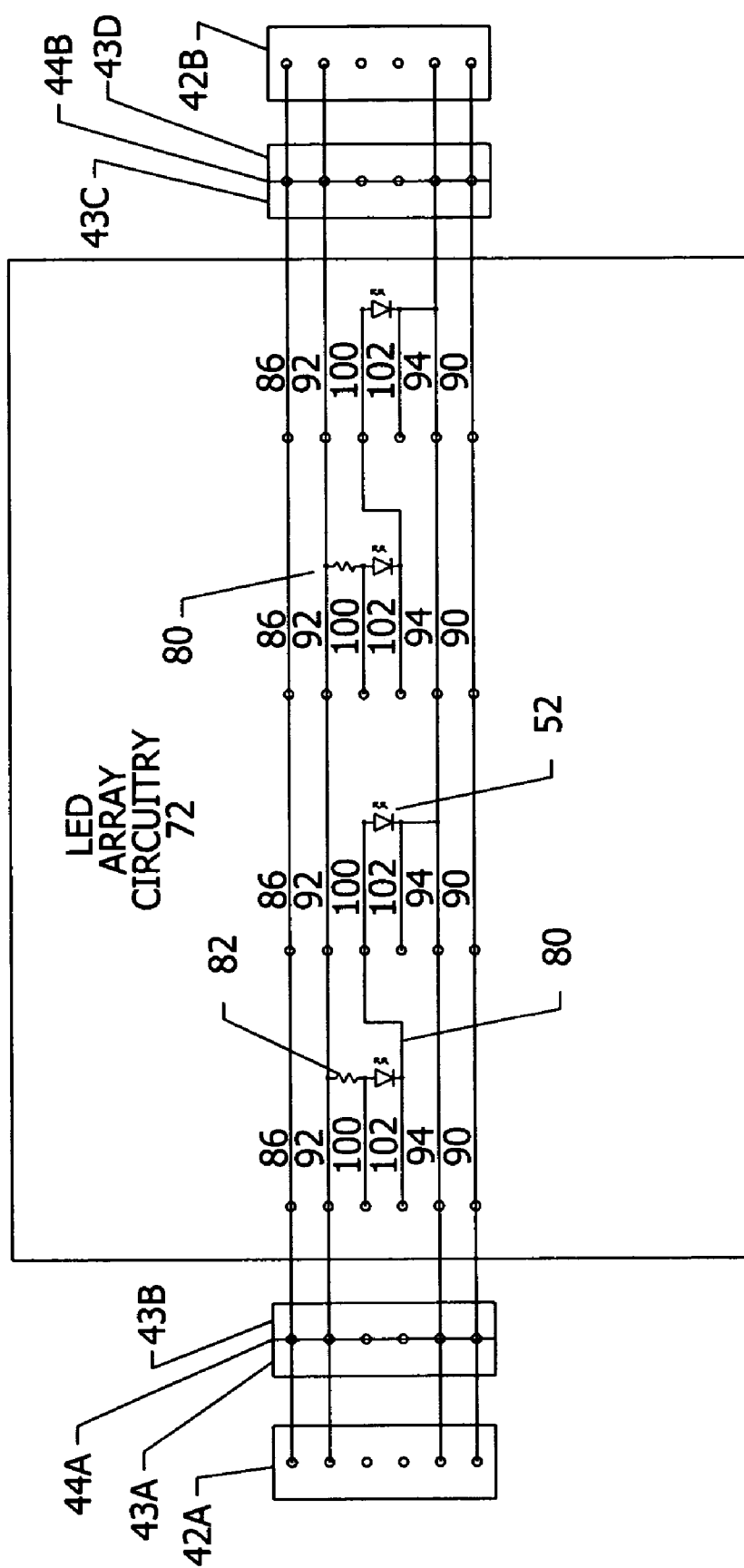


FIG. 4D

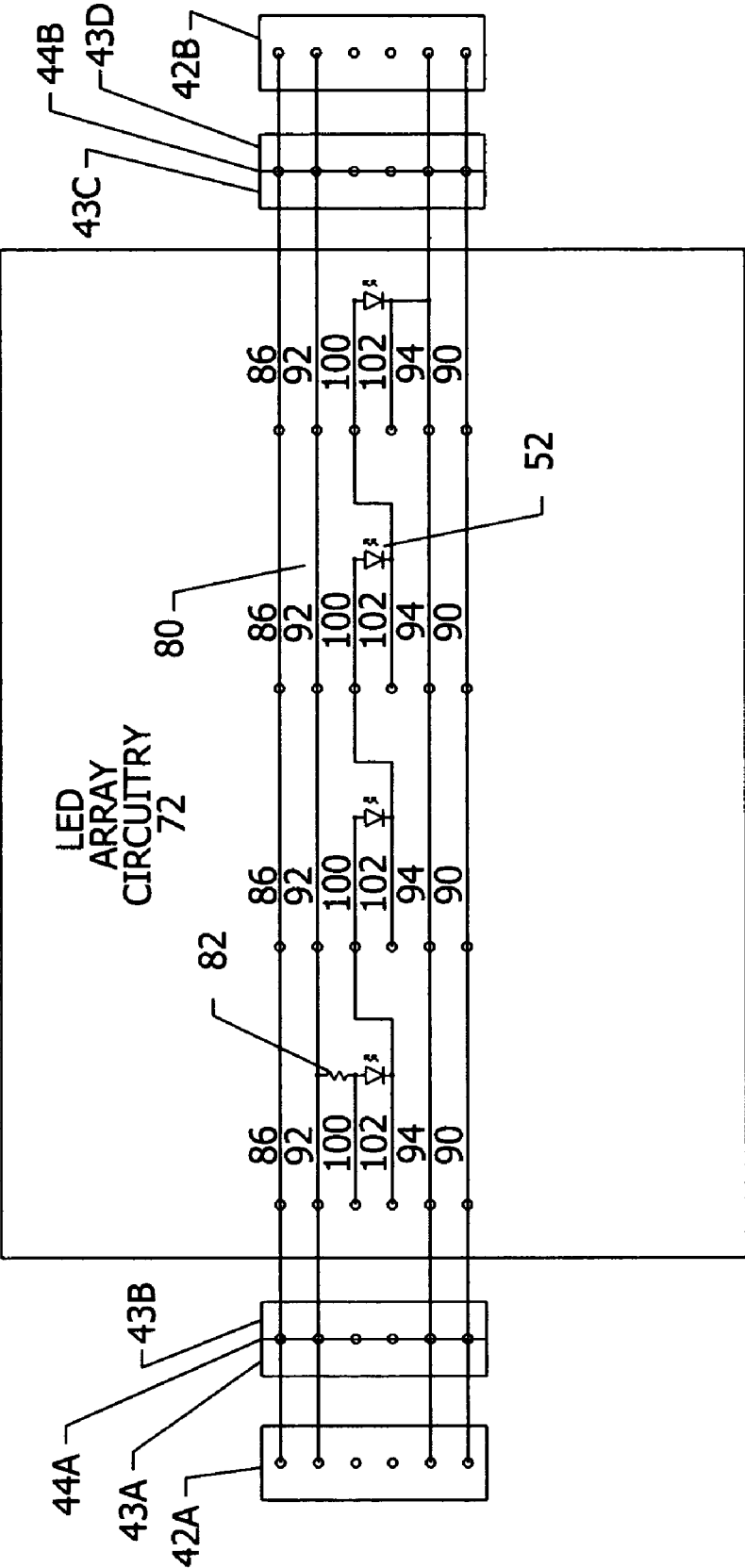


FIG. 4E

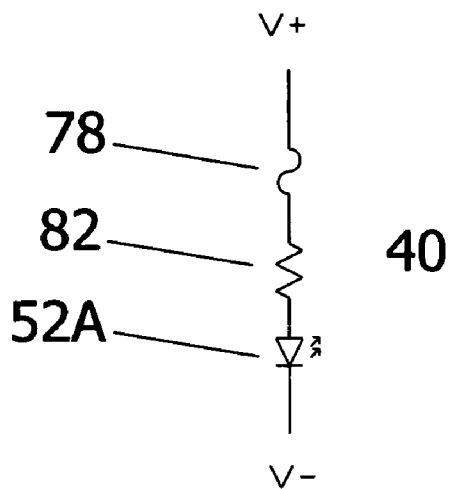


FIG. 4F

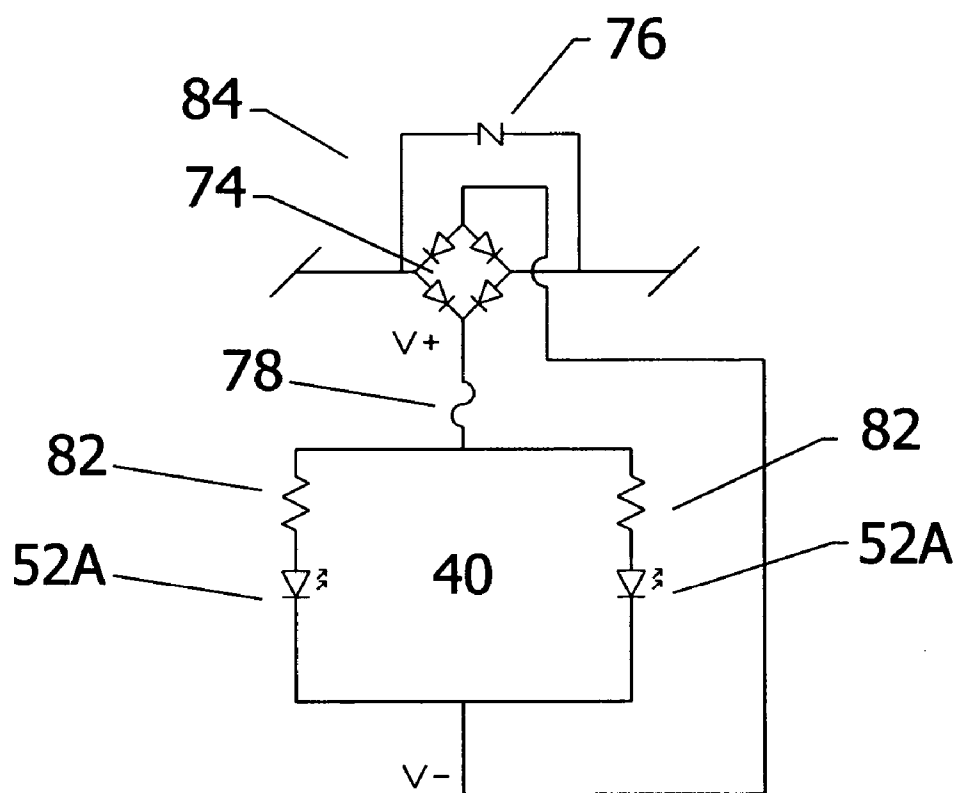
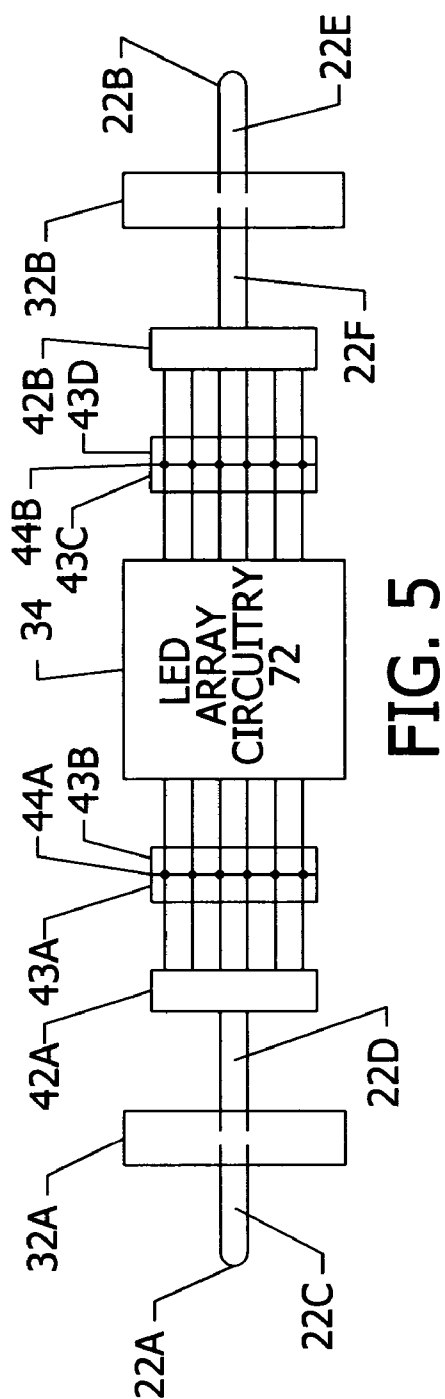
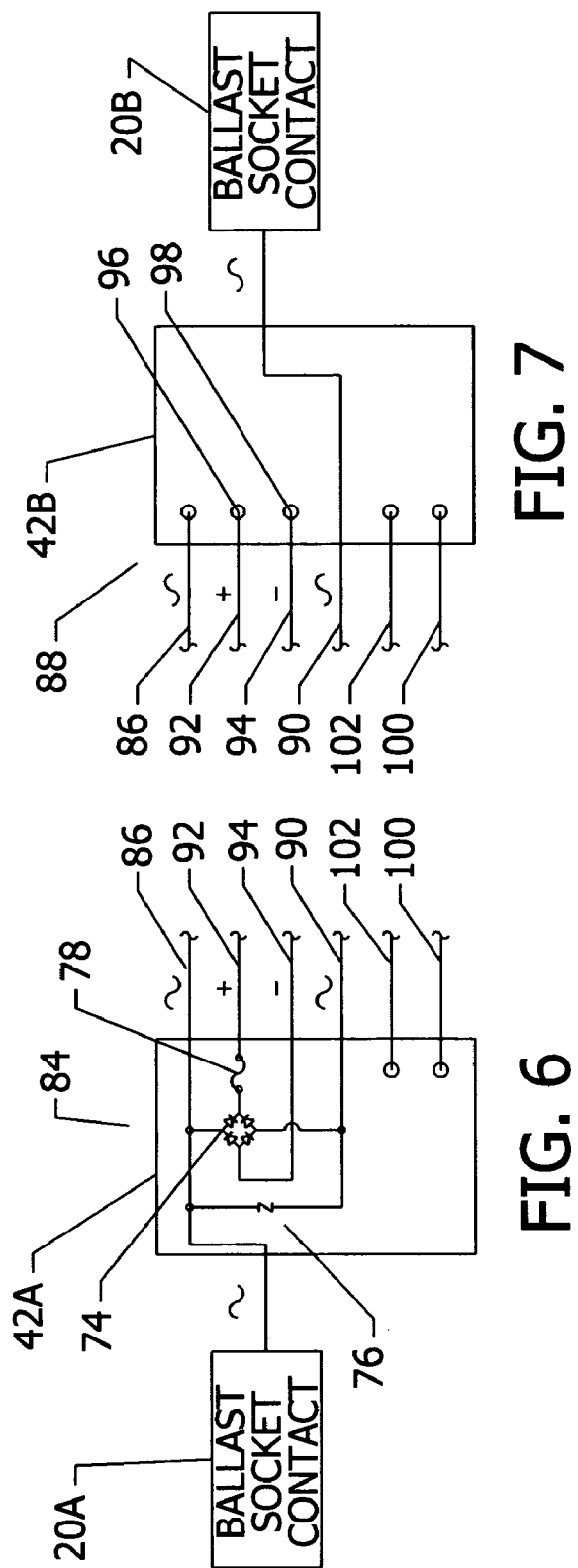


FIG. 4G



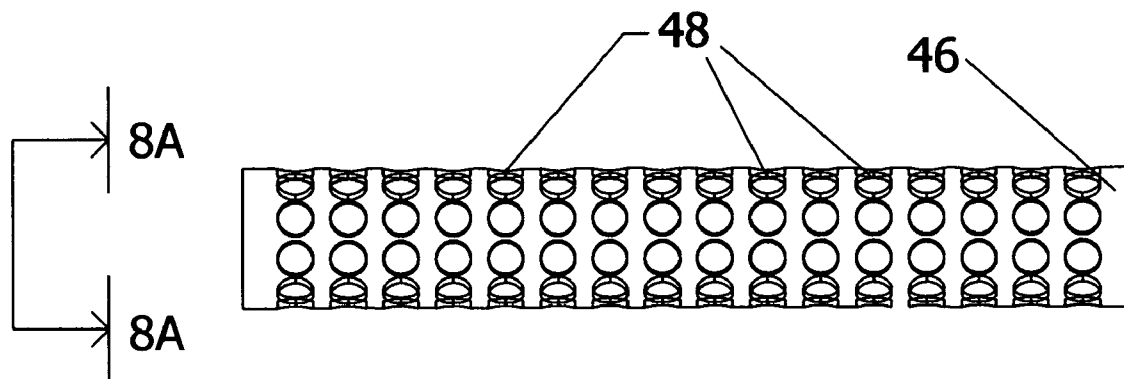


FIG. 8

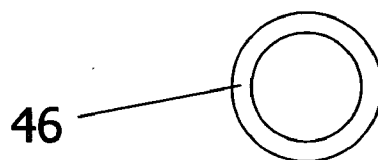


FIG. 8A

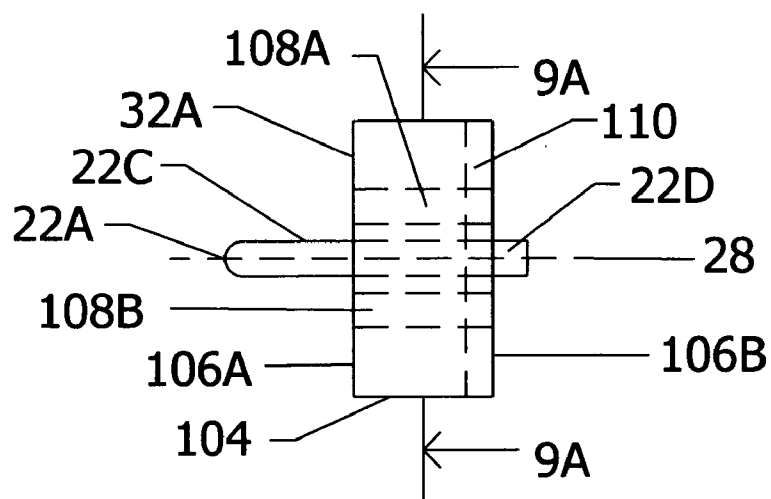


FIG. 9

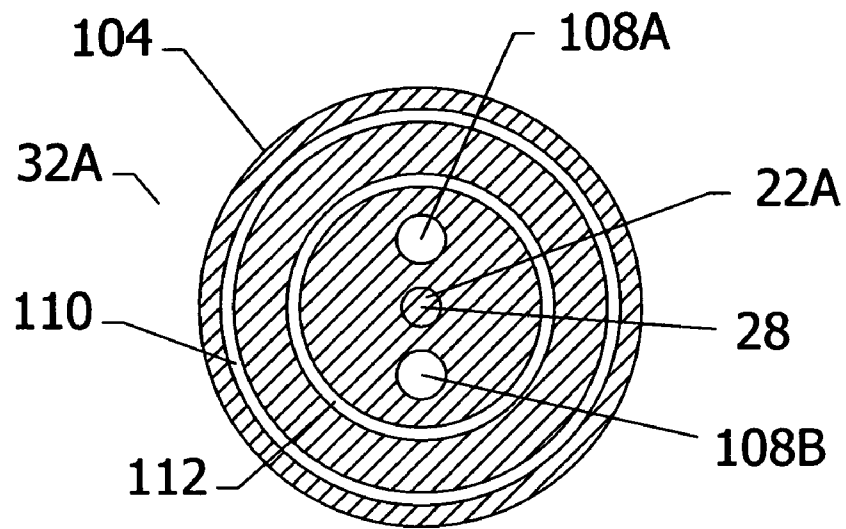


FIG. 9A

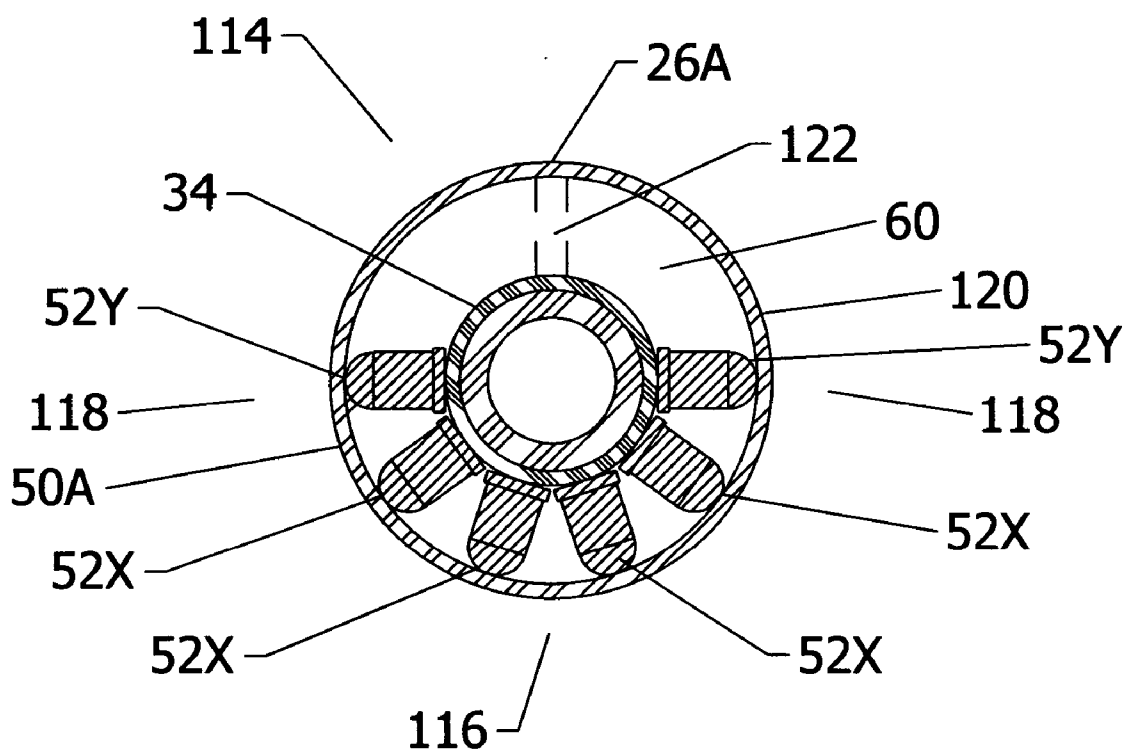
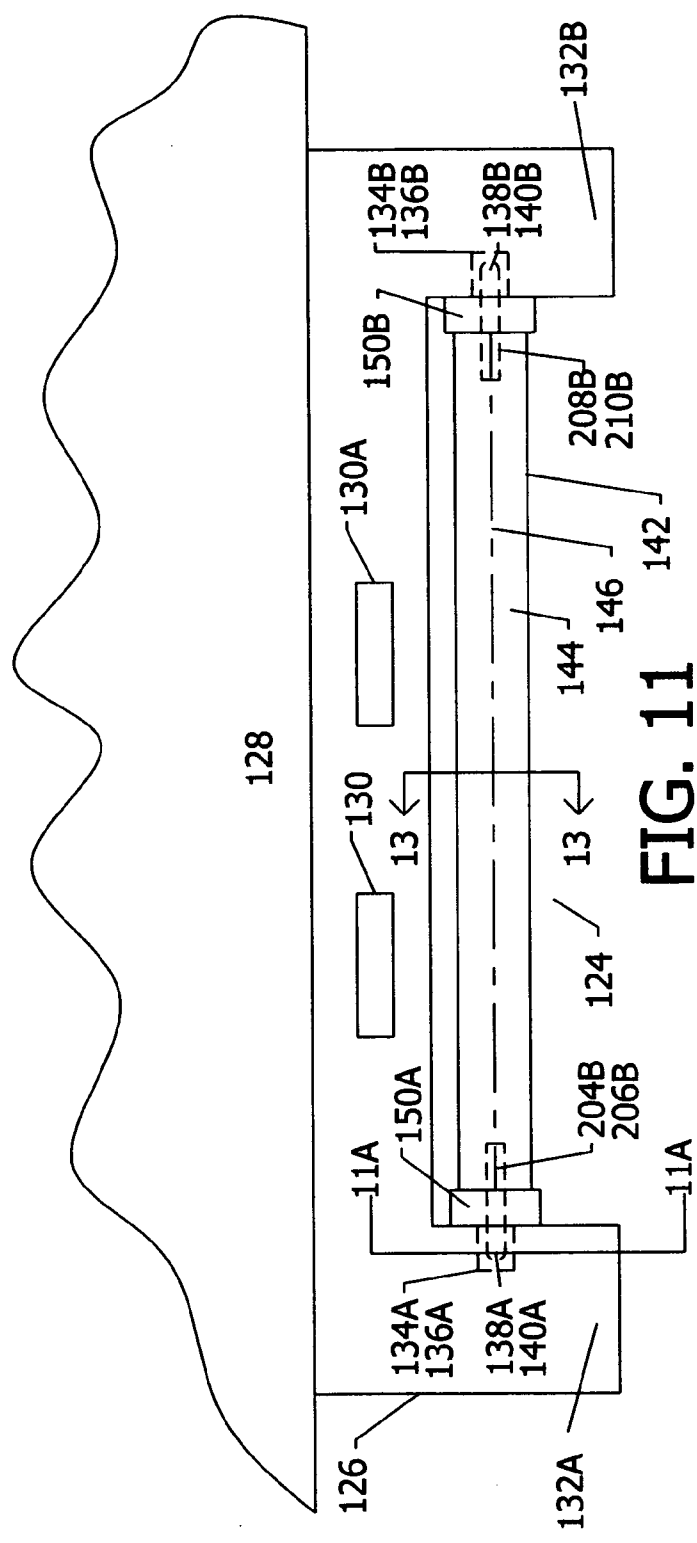
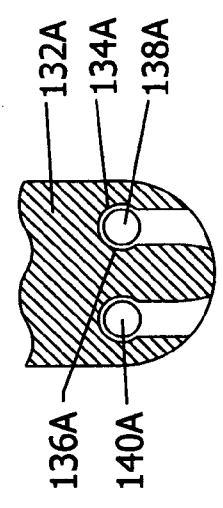
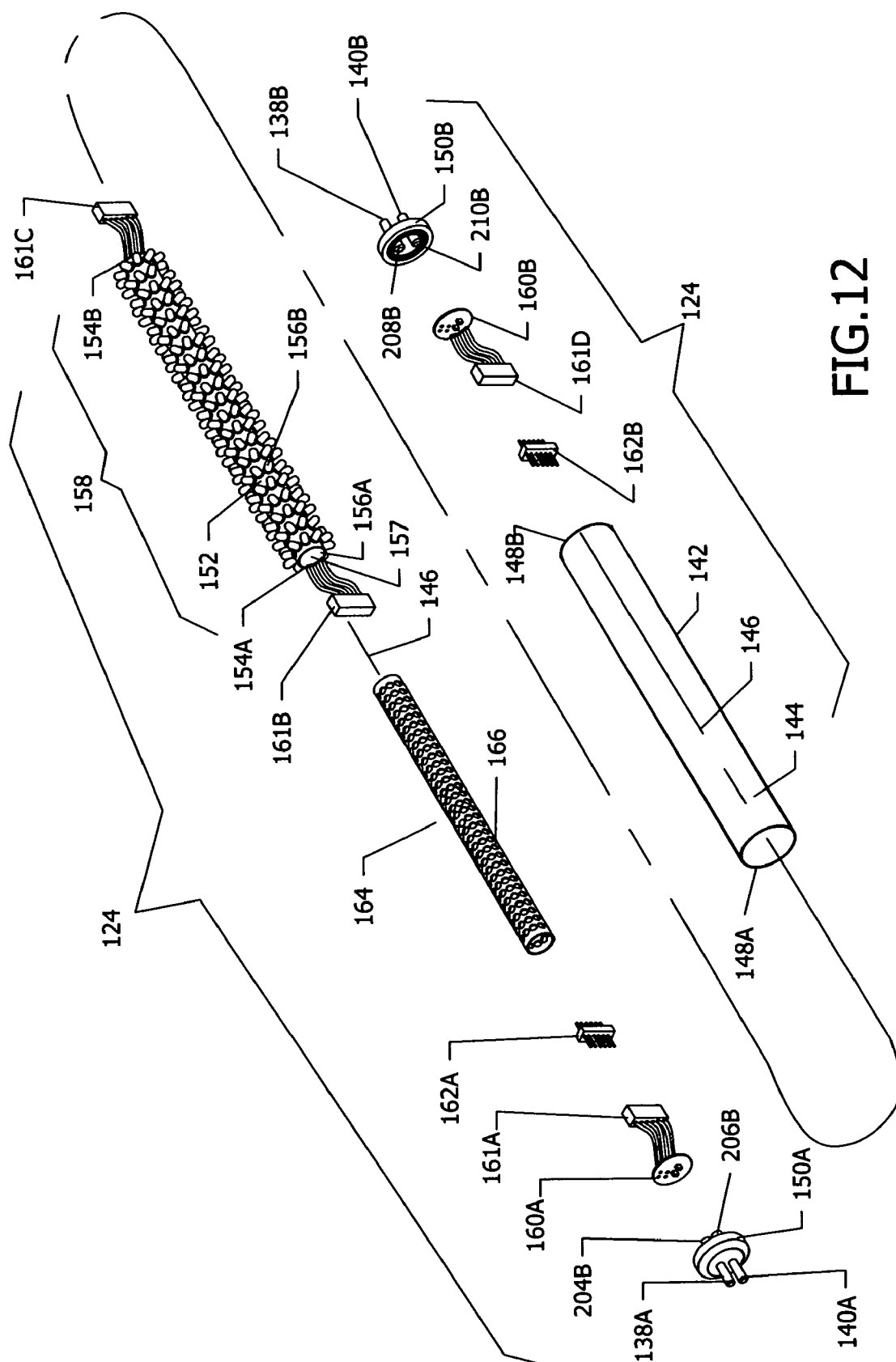


FIG. 10



+



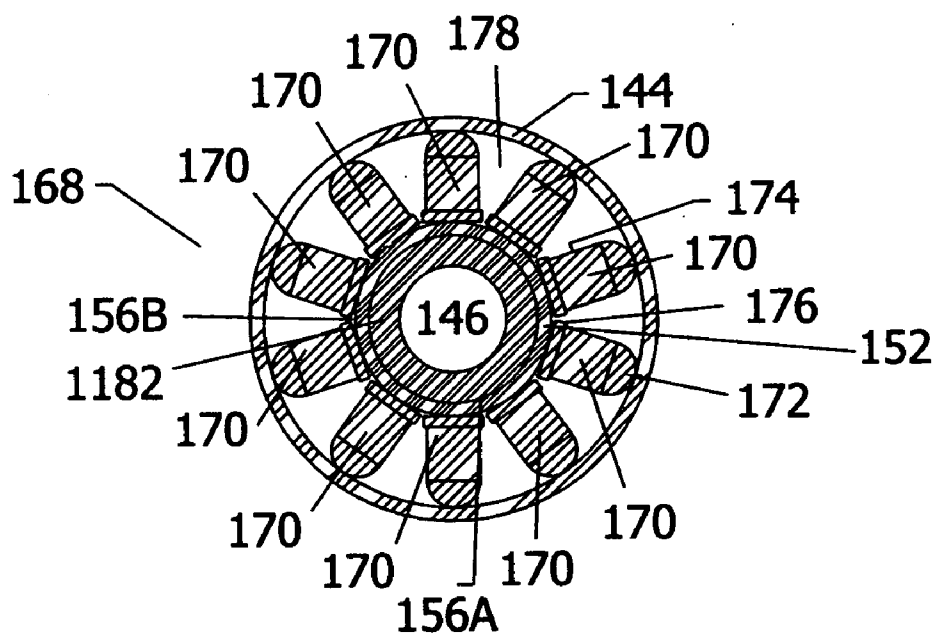


FIG. 13

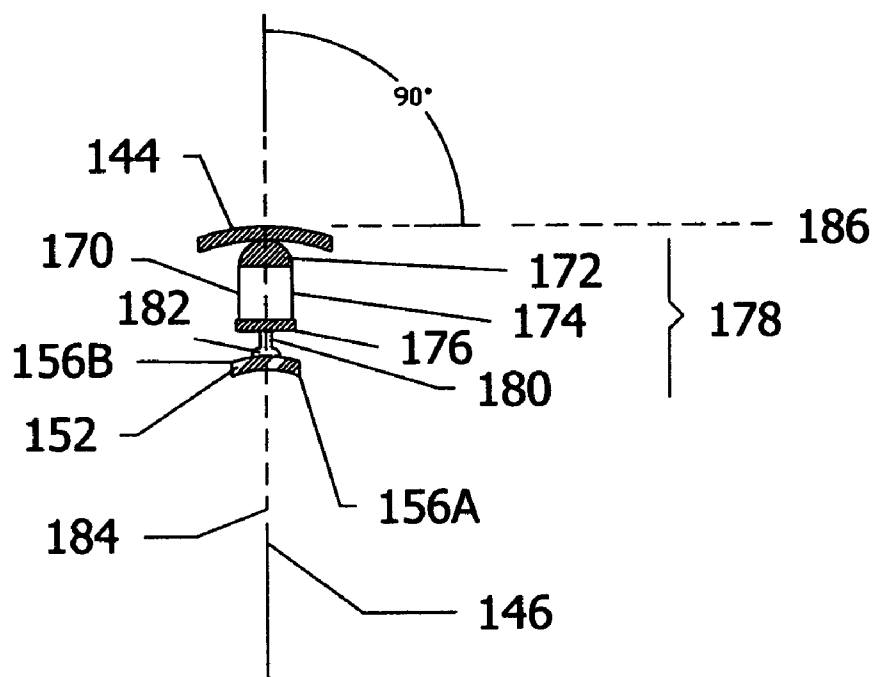
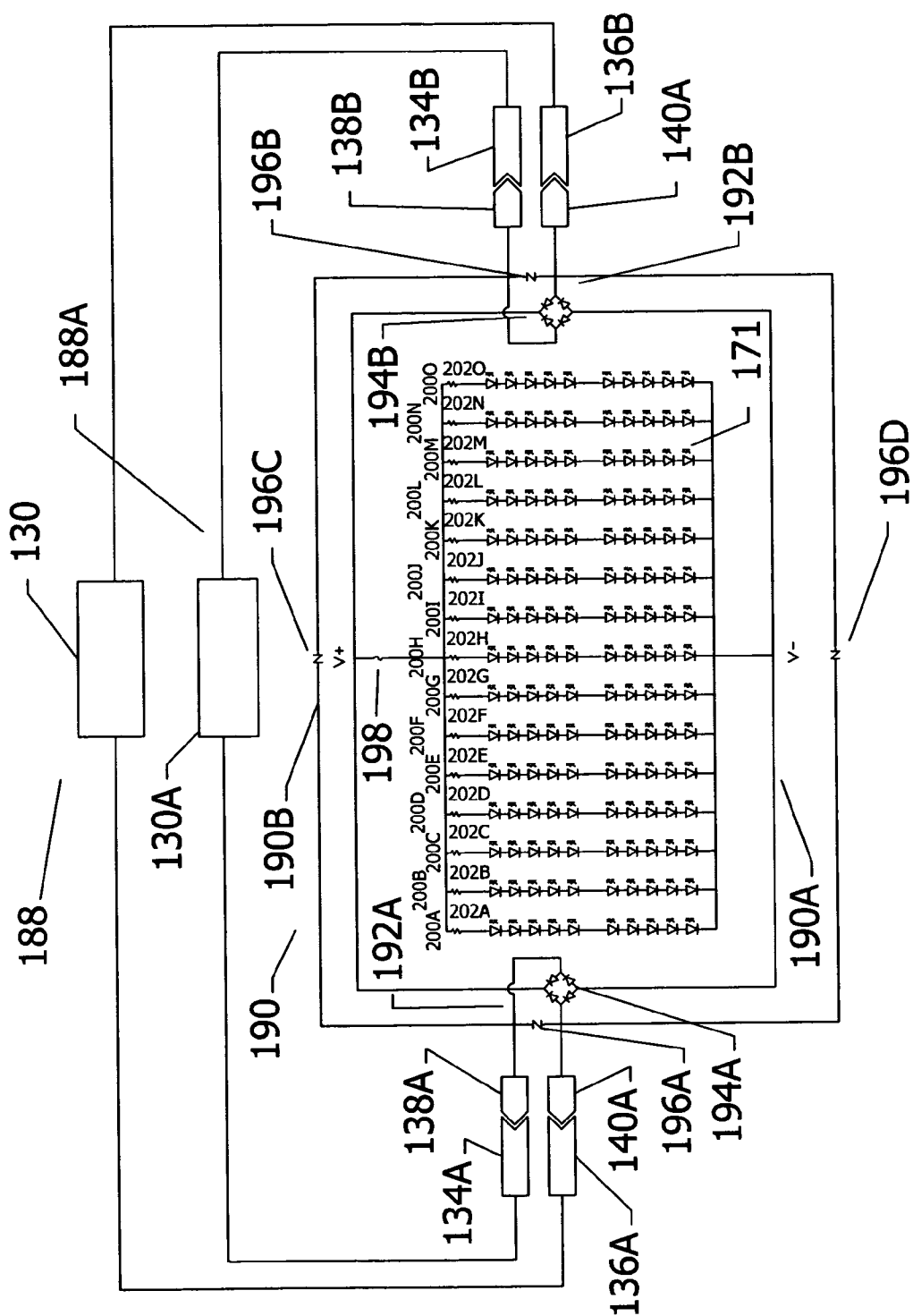
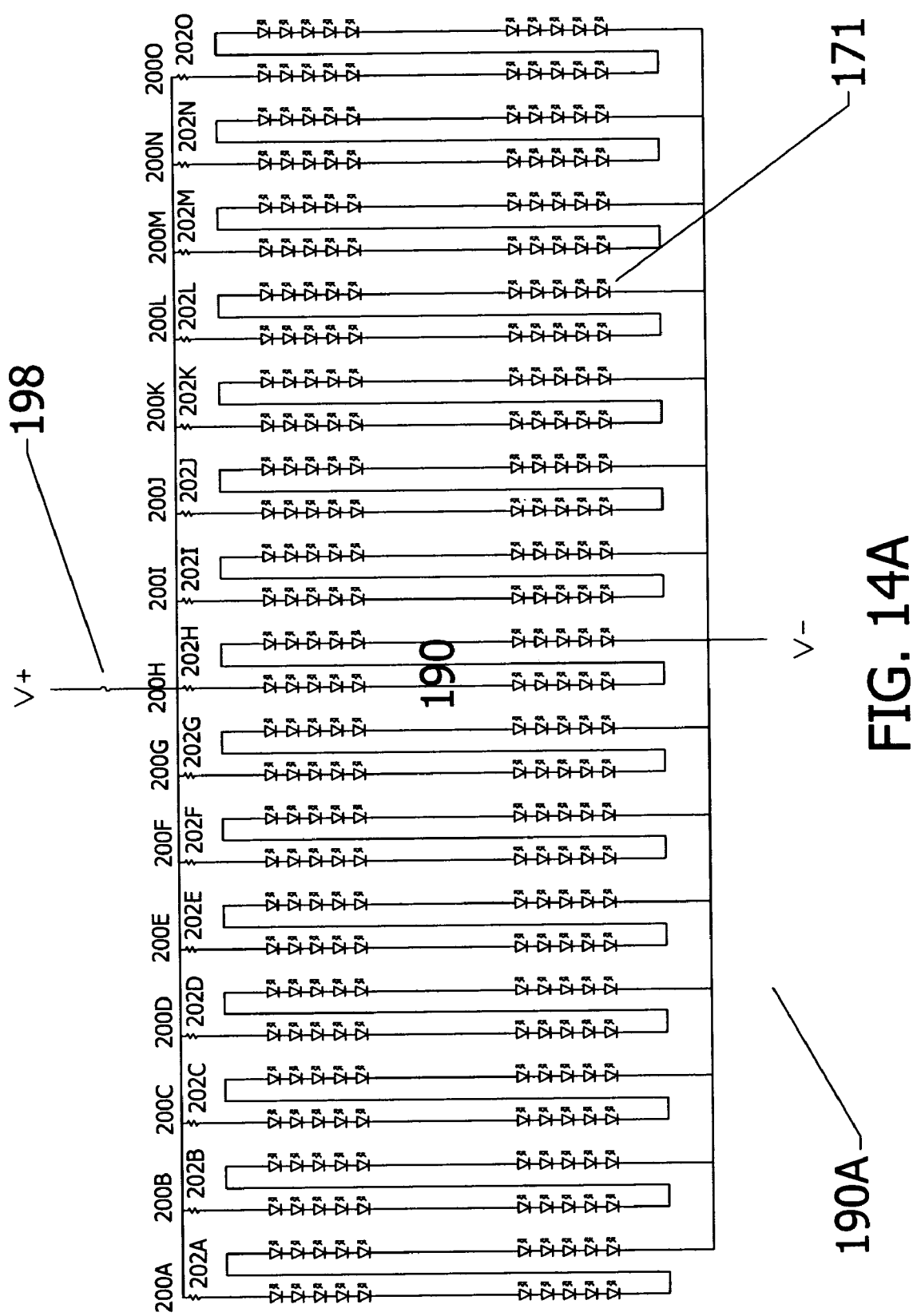


FIG. 13A





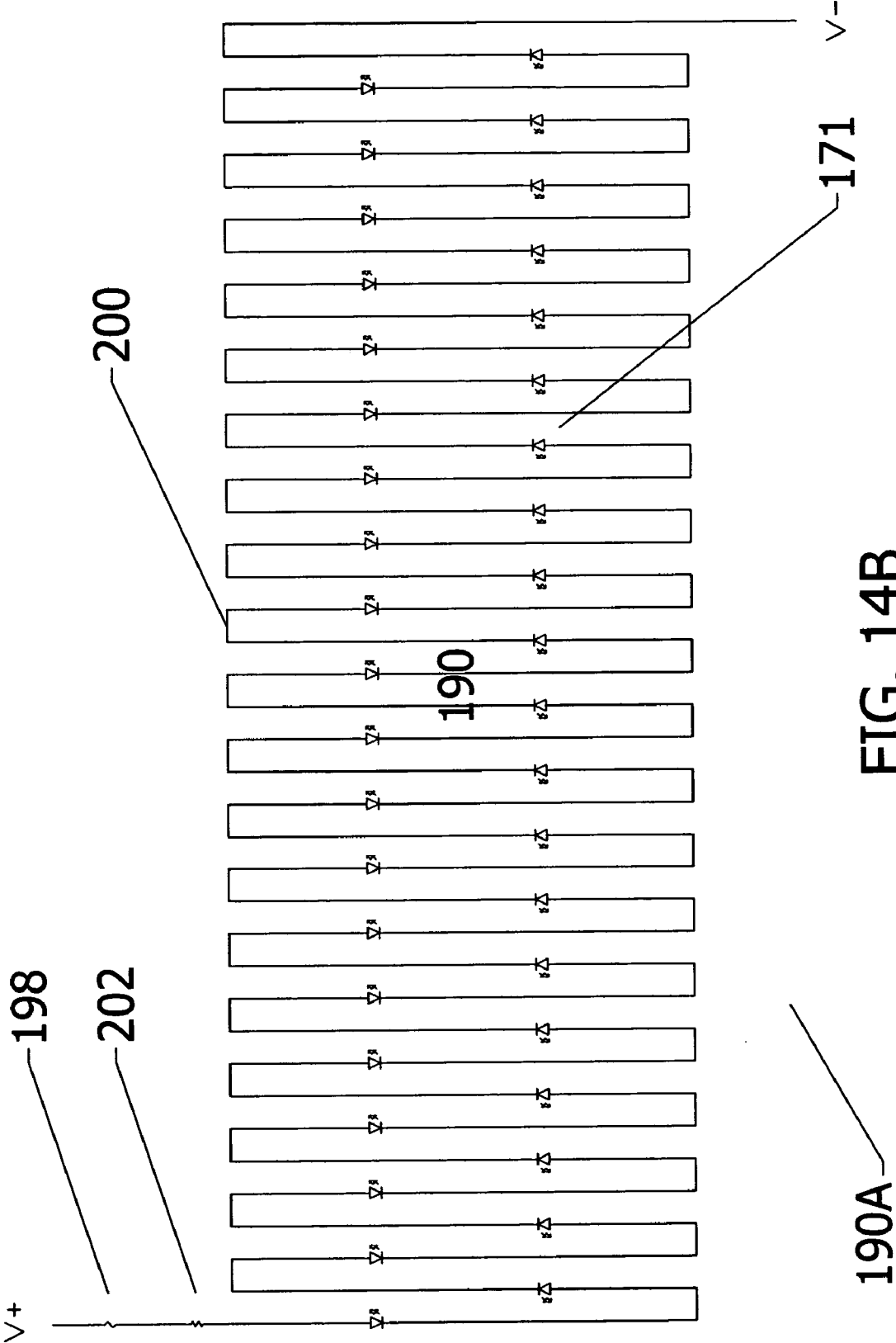


FIG. 14B

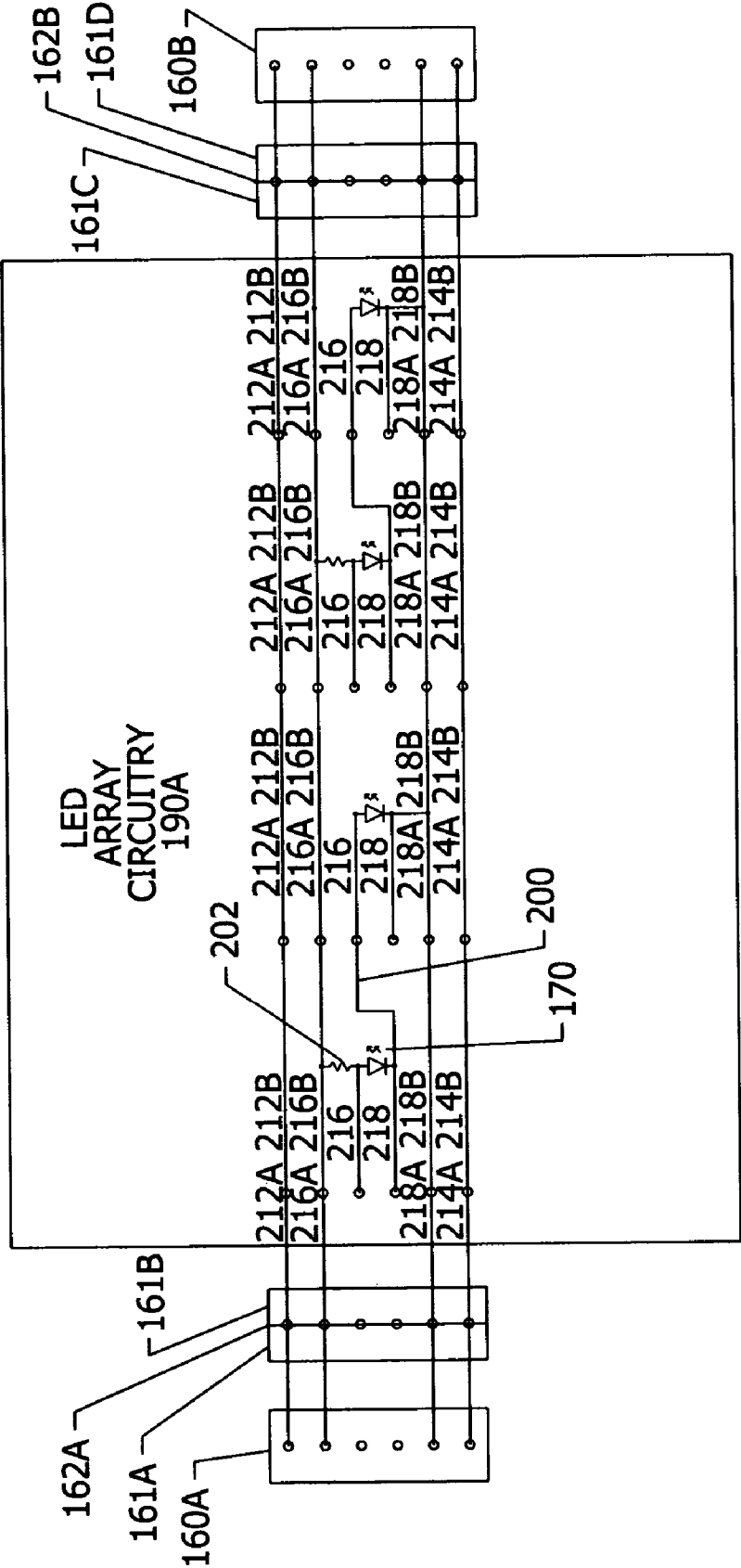


FIG. 14D

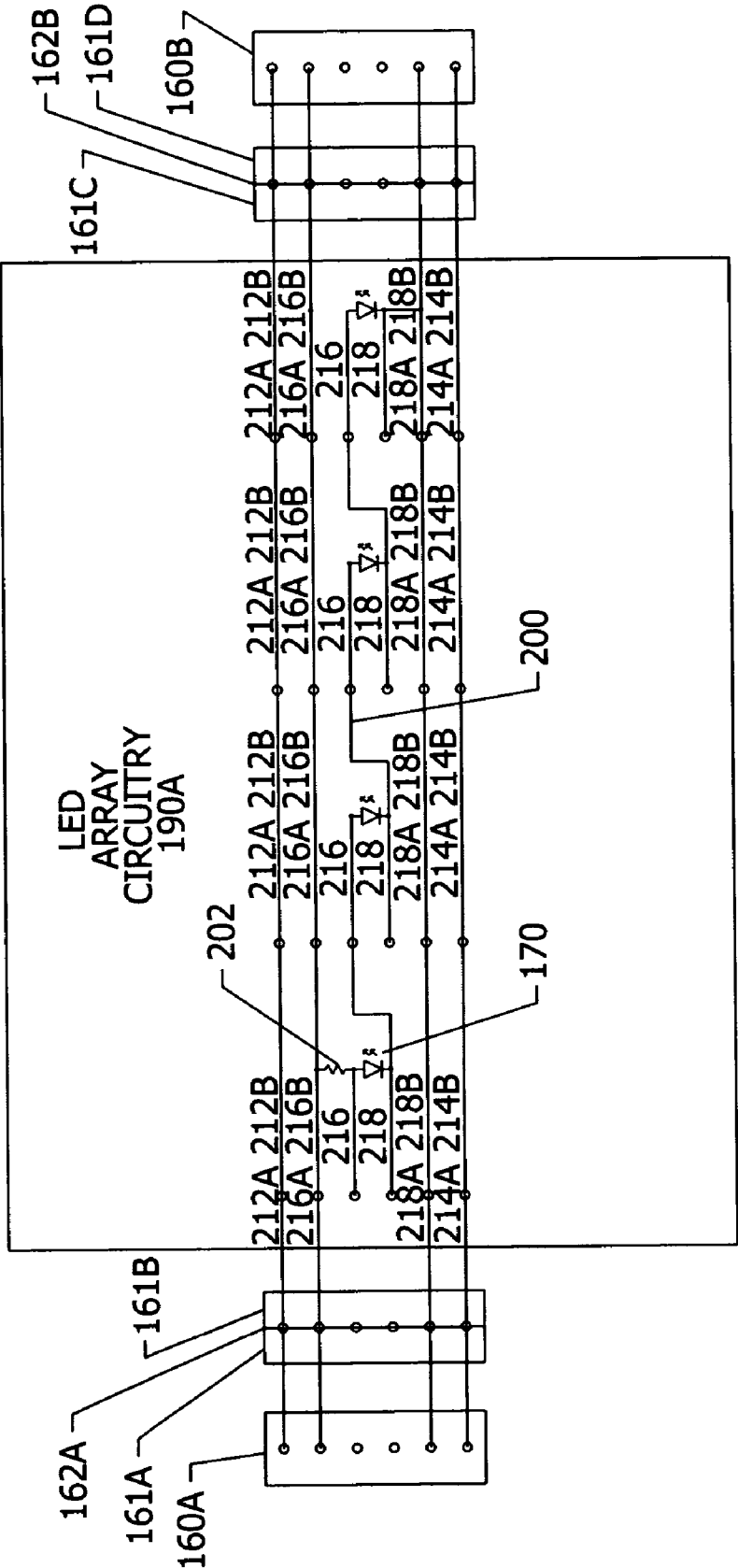


FIG. 14E

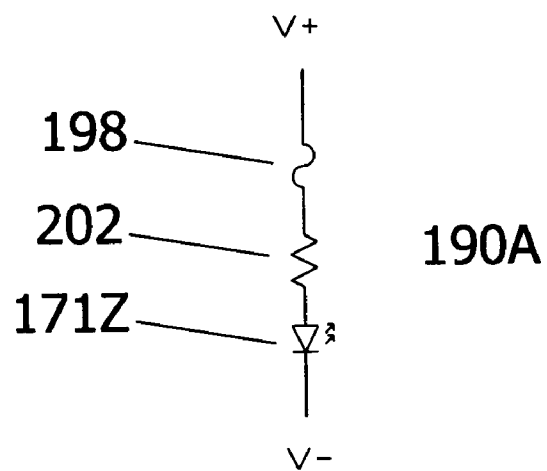


FIG. 14F

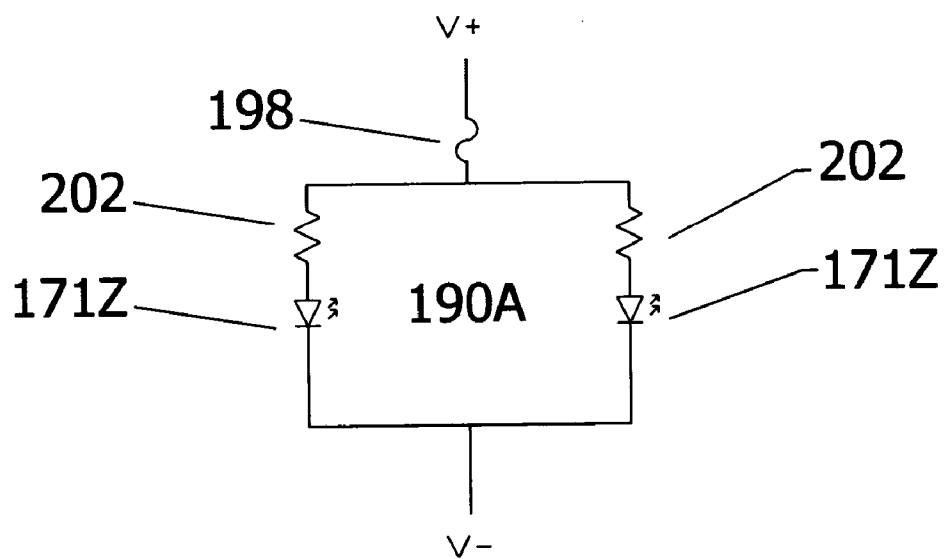
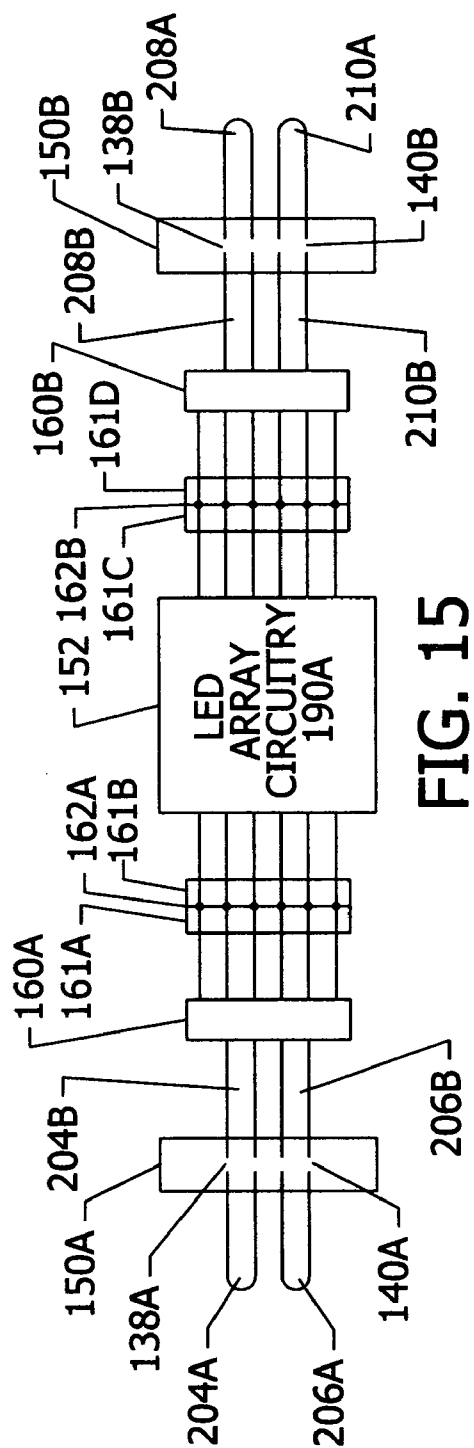
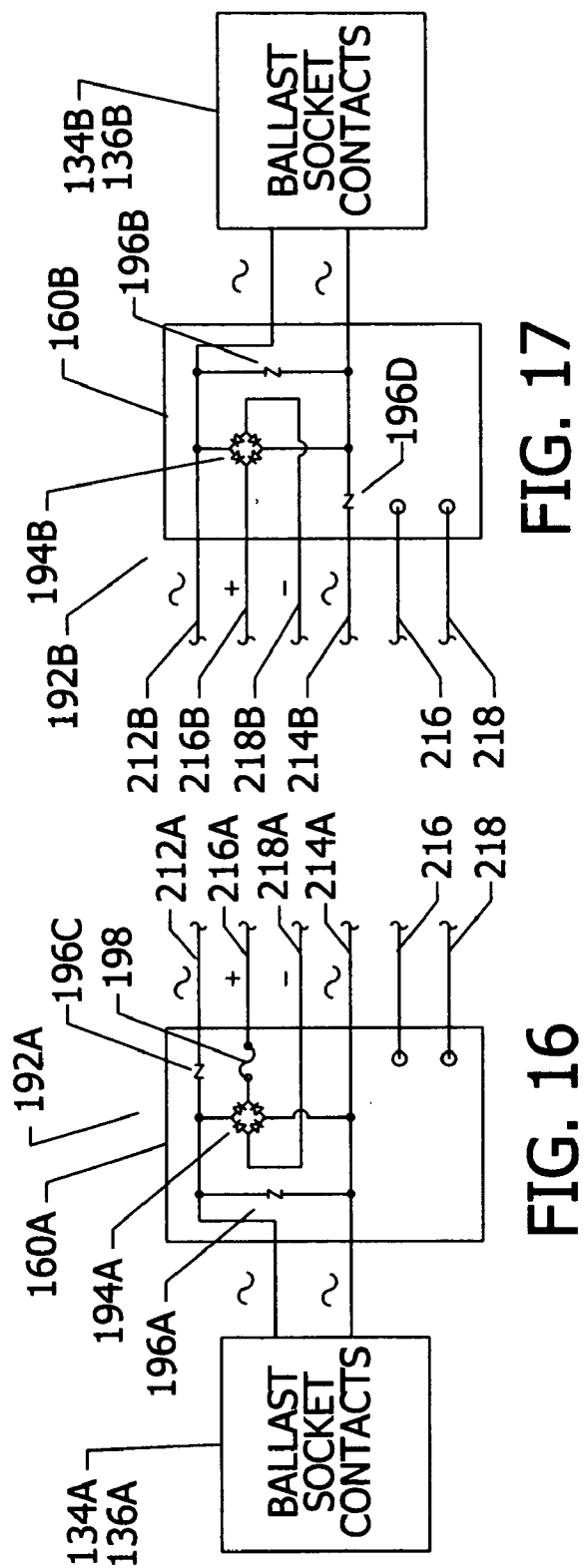


FIG. 14G



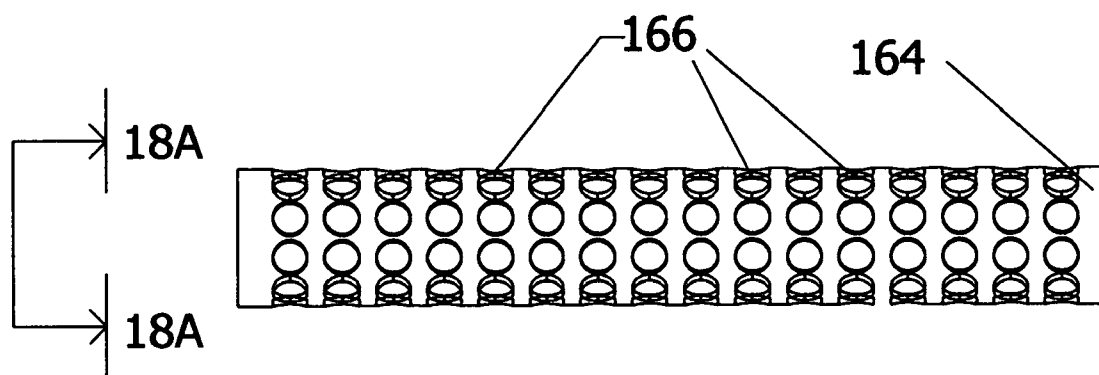


FIG. 18

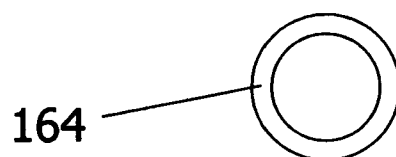


FIG. 18A

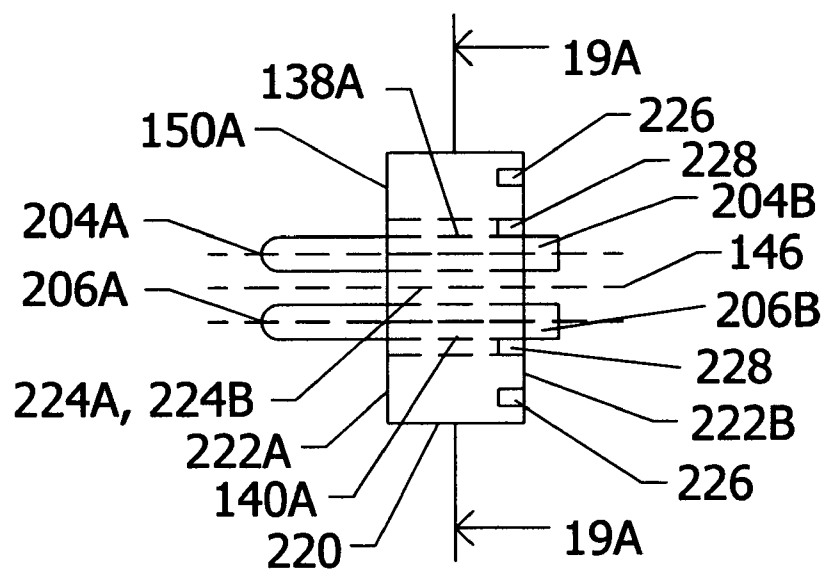


FIG. 19

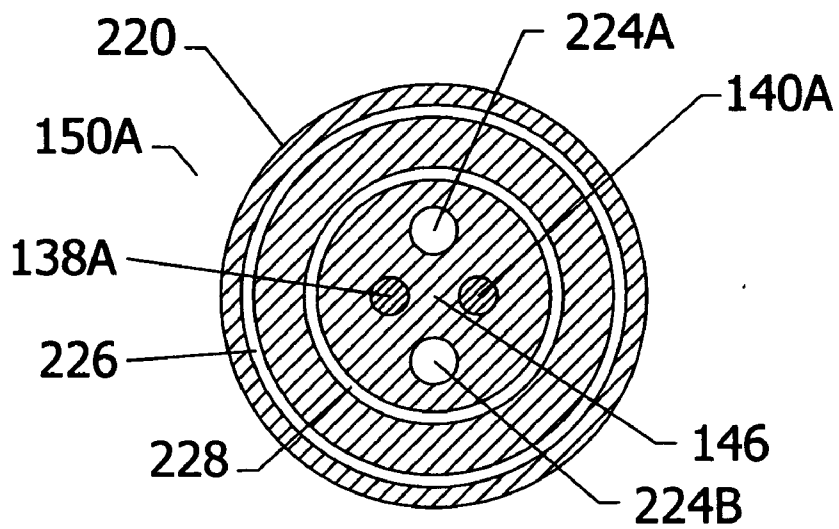


FIG. 19A

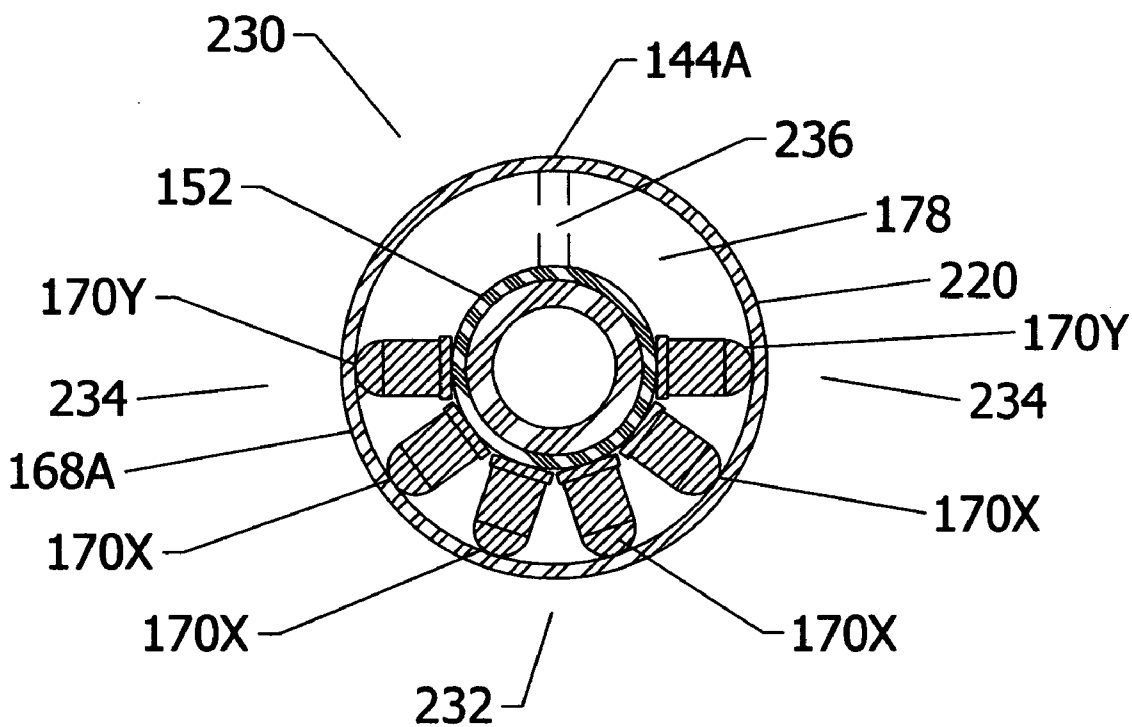


FIG. 20

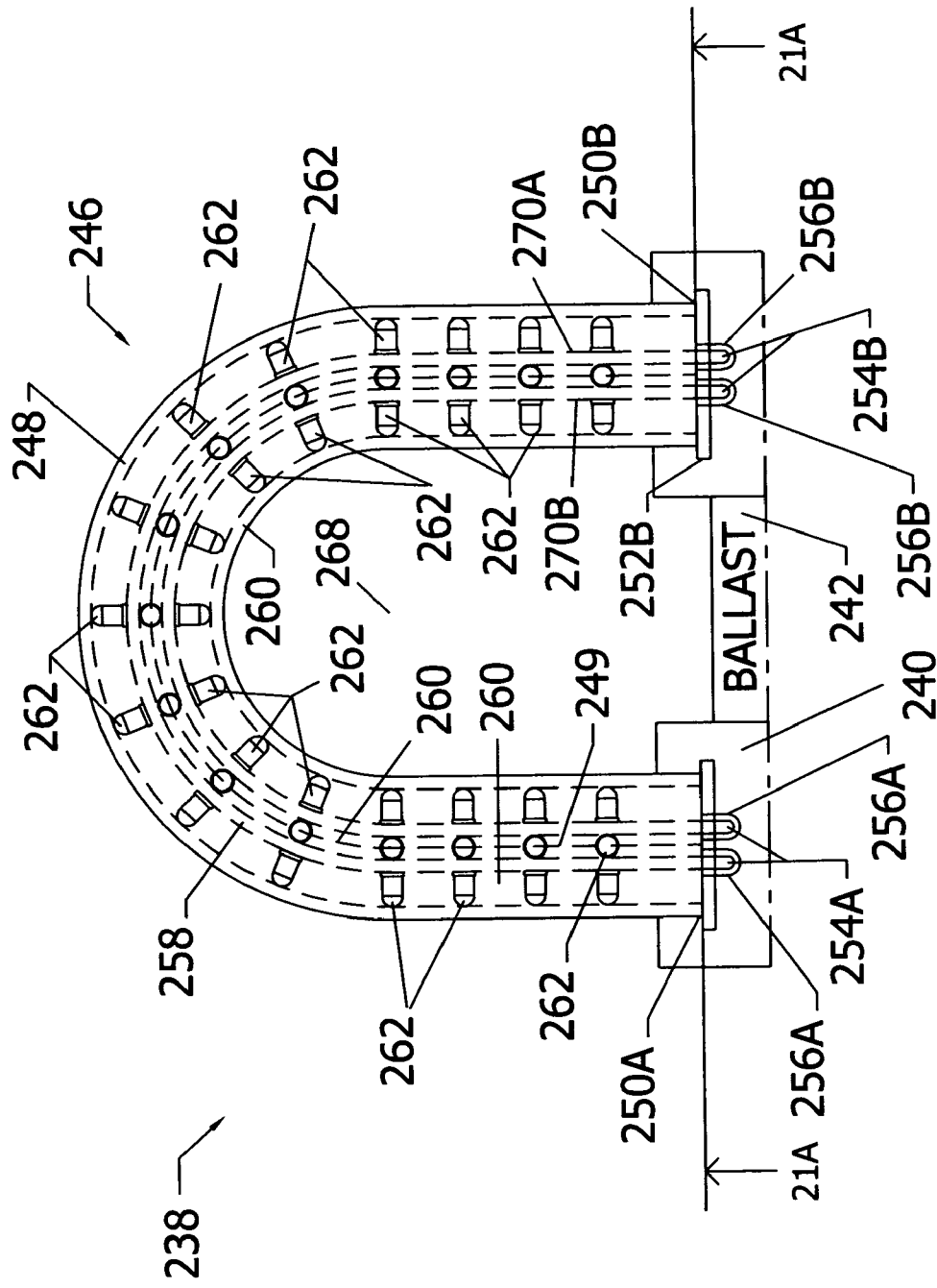


FIG. 21

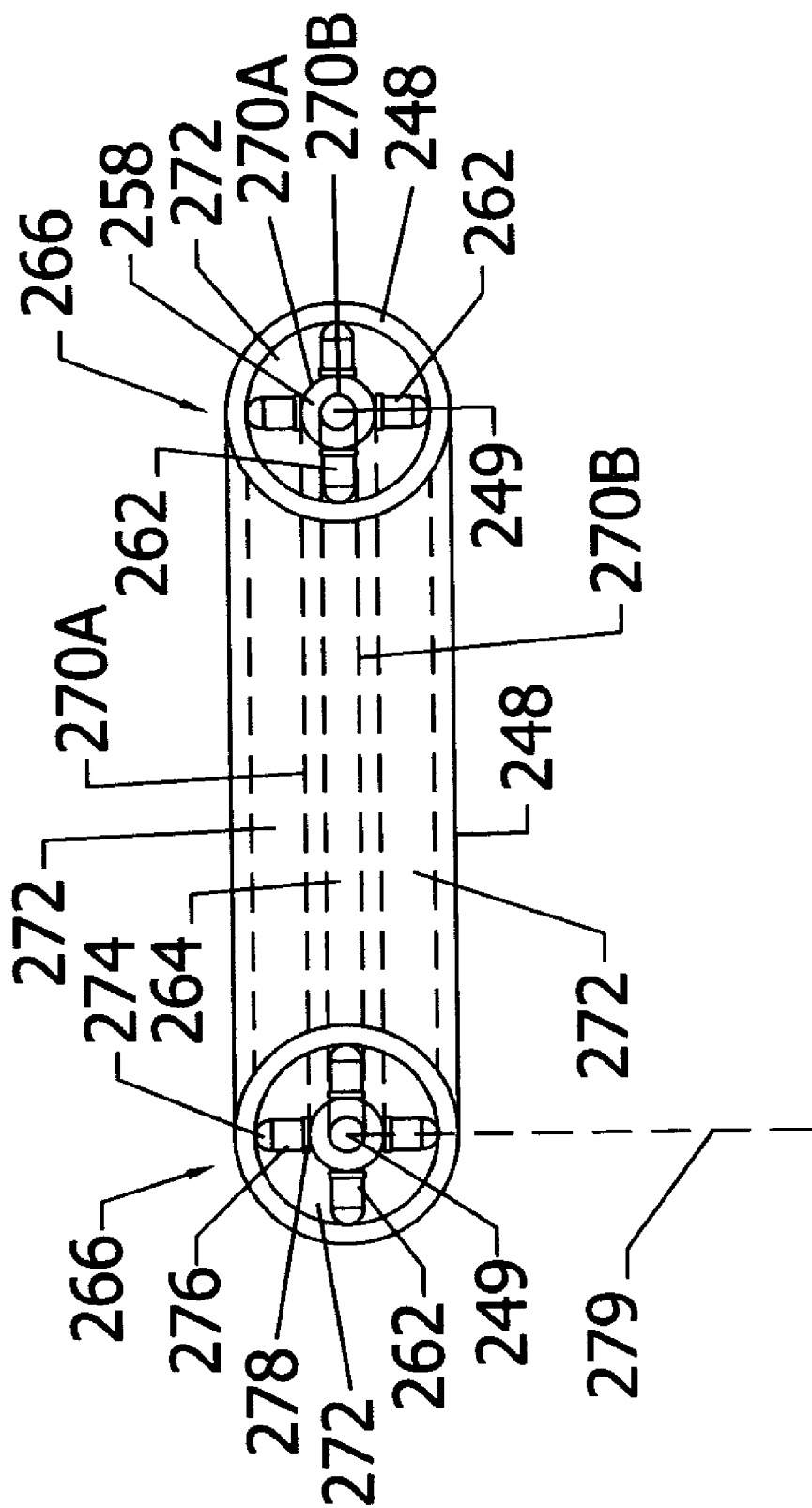


FIG 21A

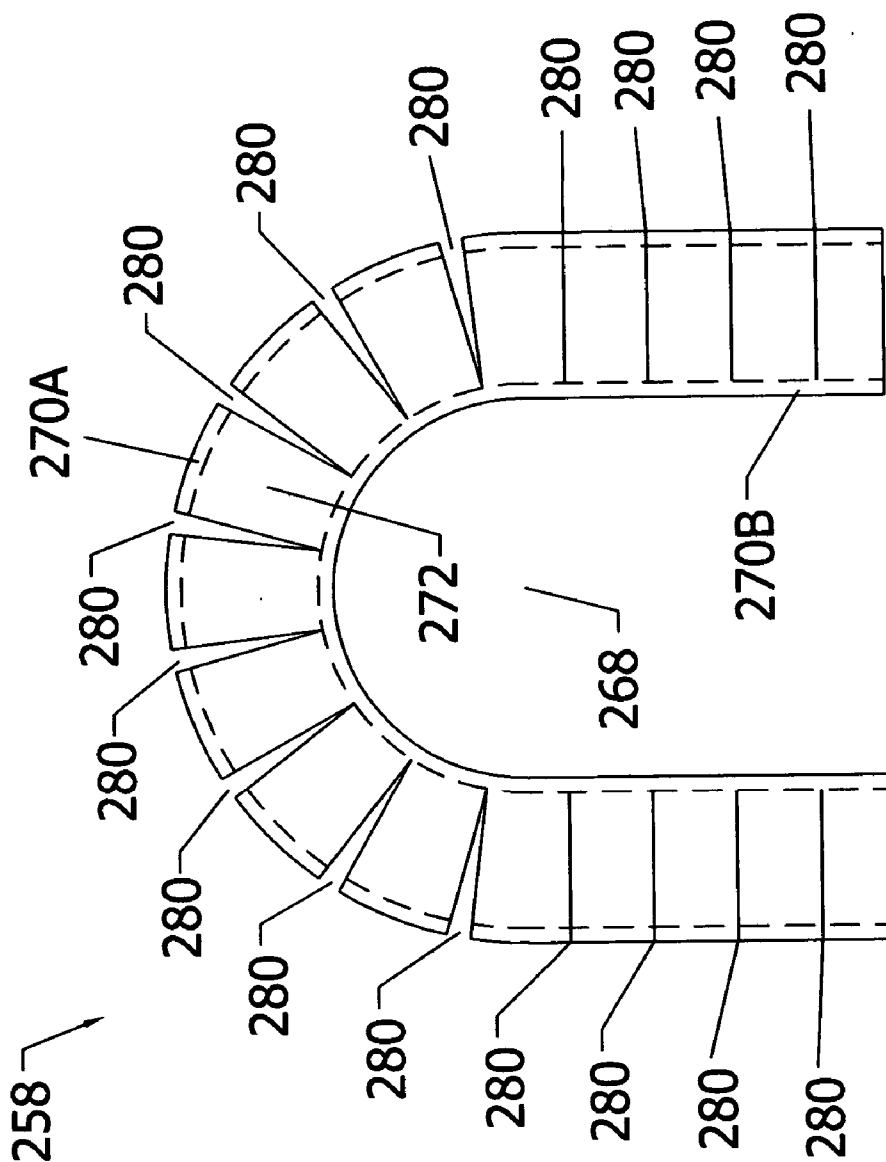


FIG 22

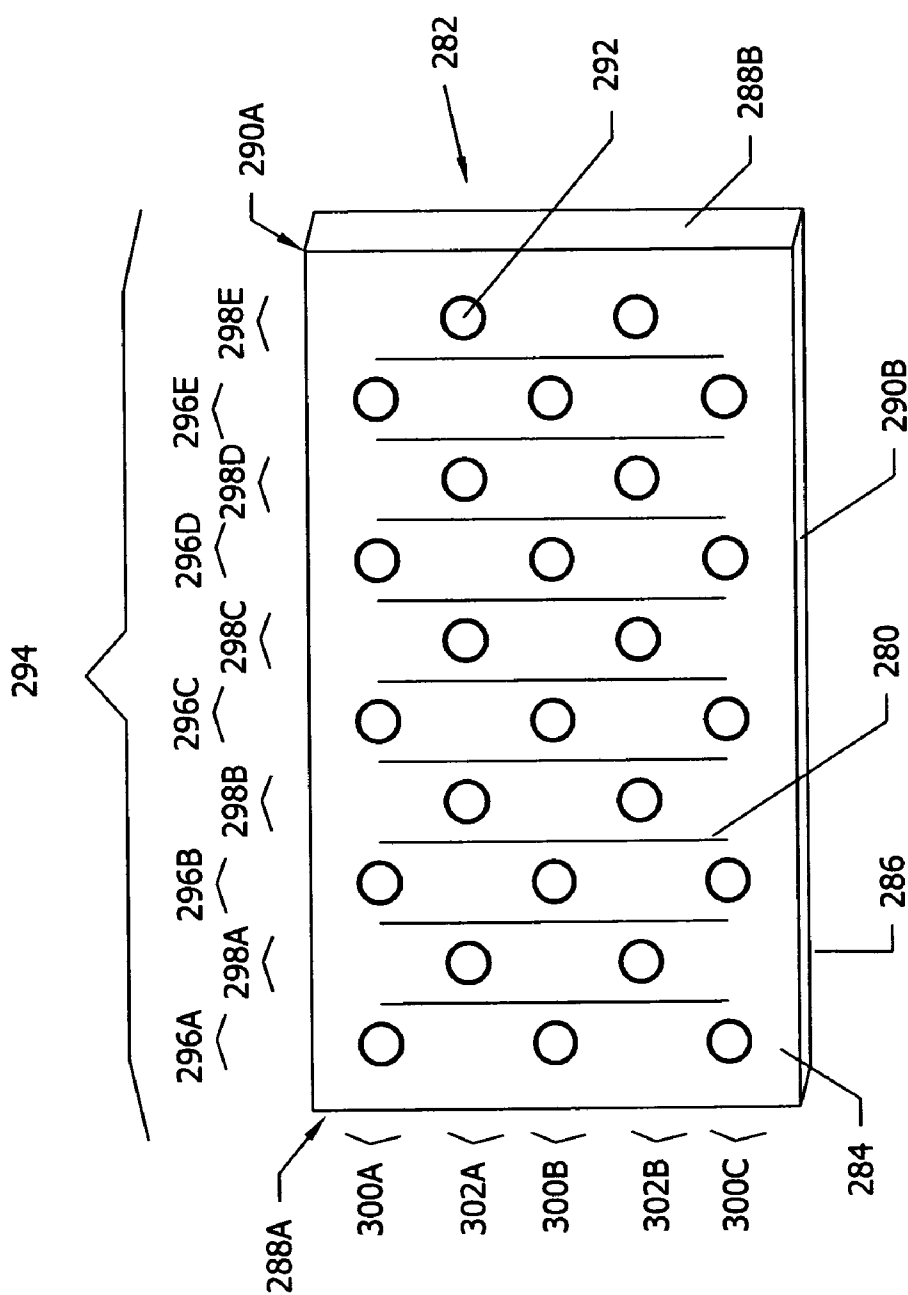


FIG 23

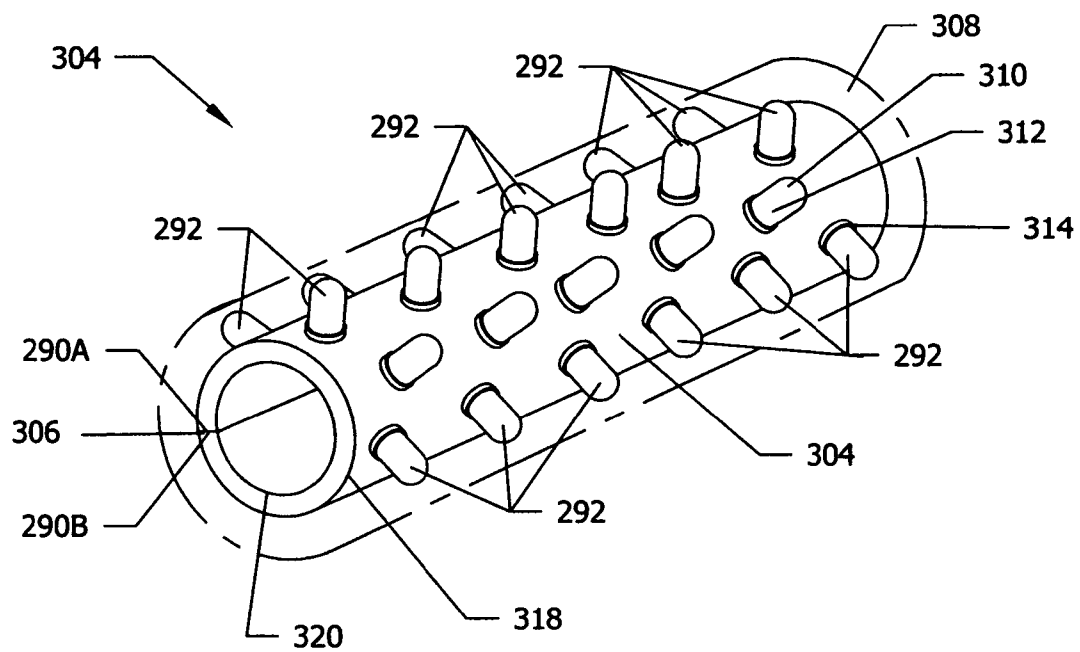


FIG 24

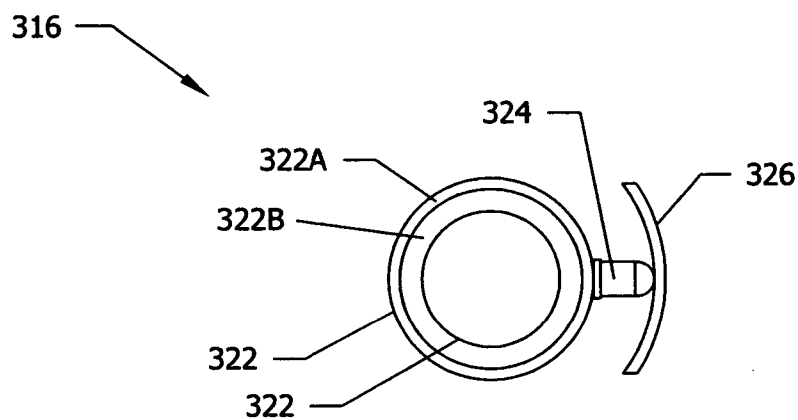


FIG 25

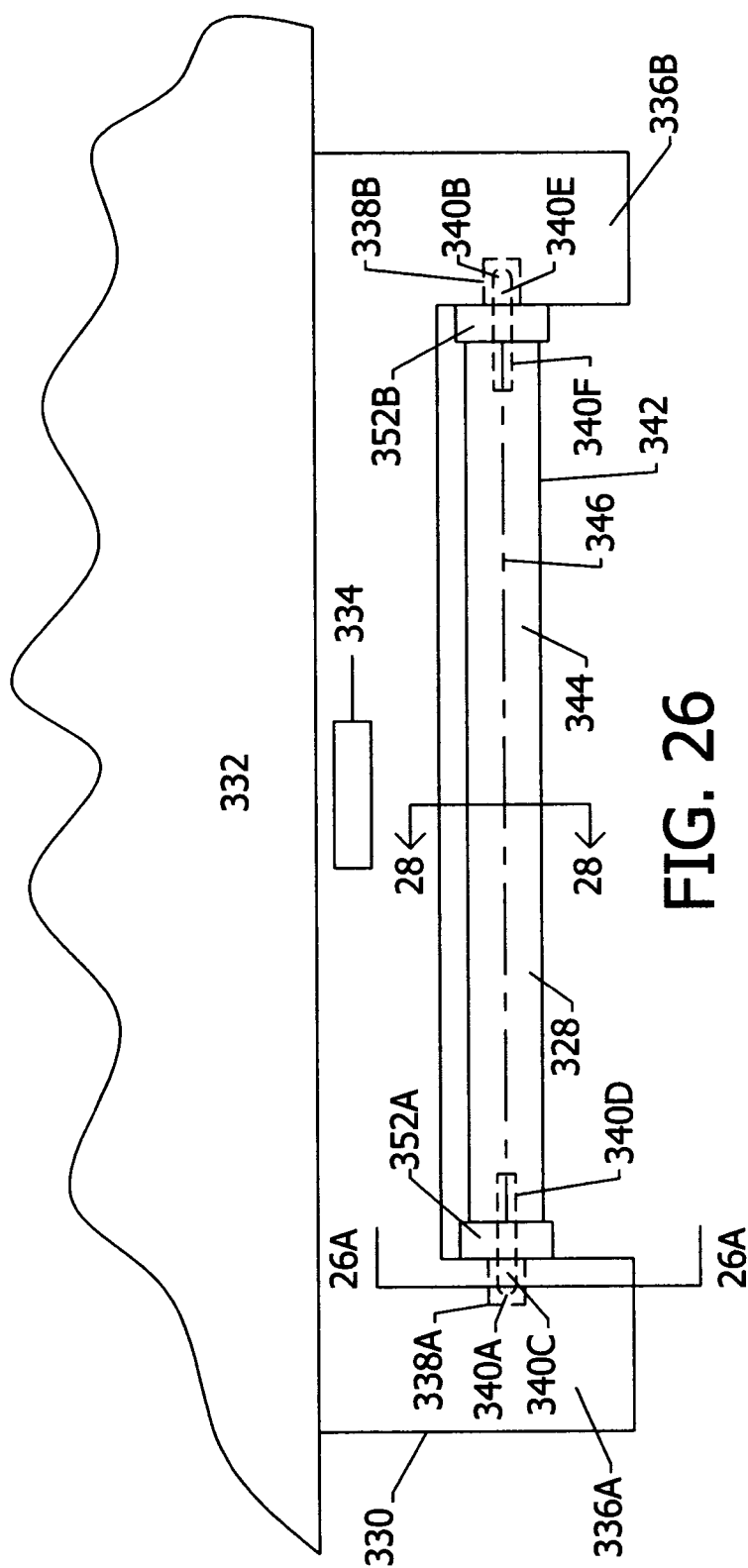


FIG. 26

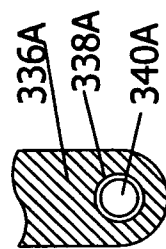


FIG. 26A

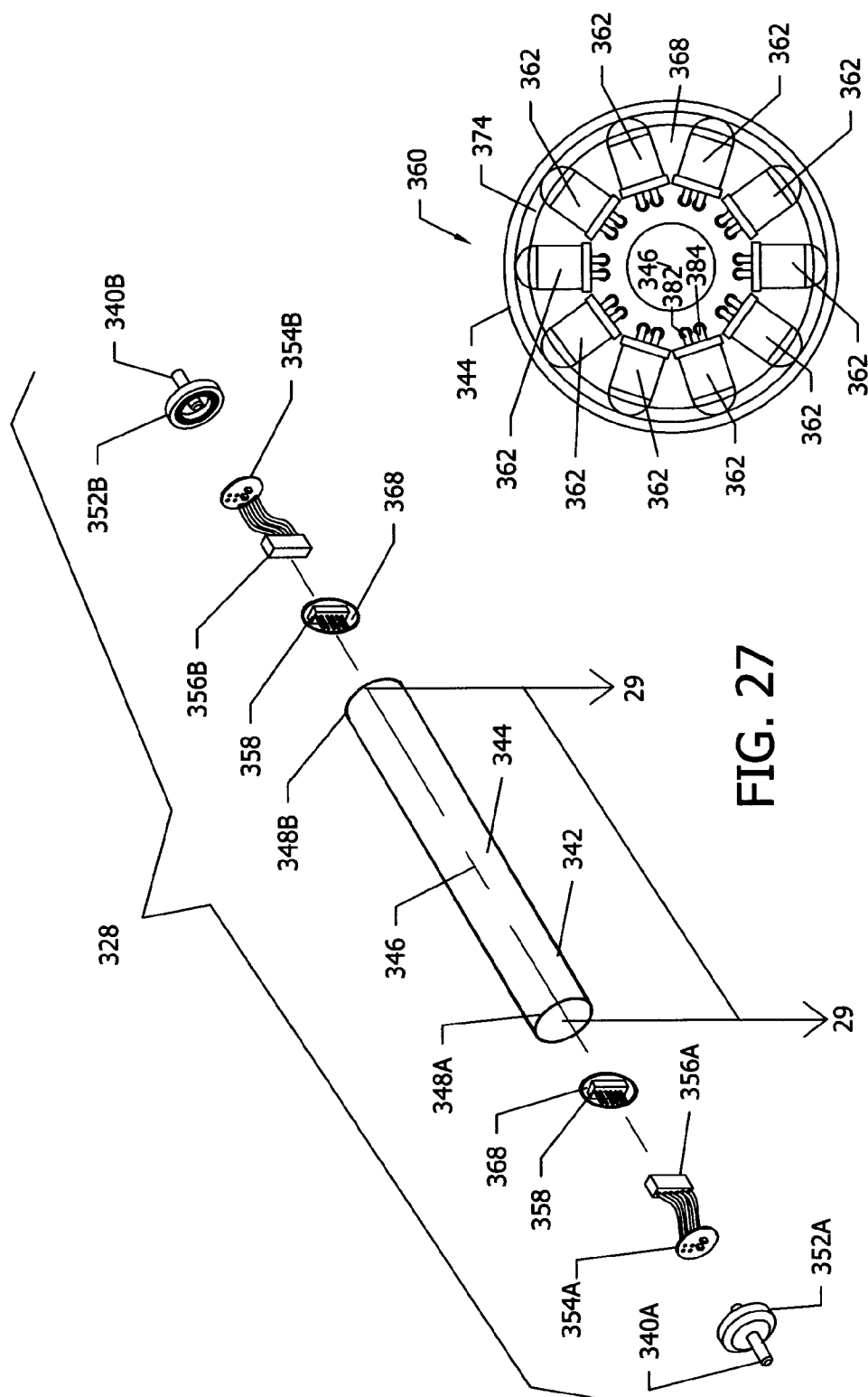


FIG. 28

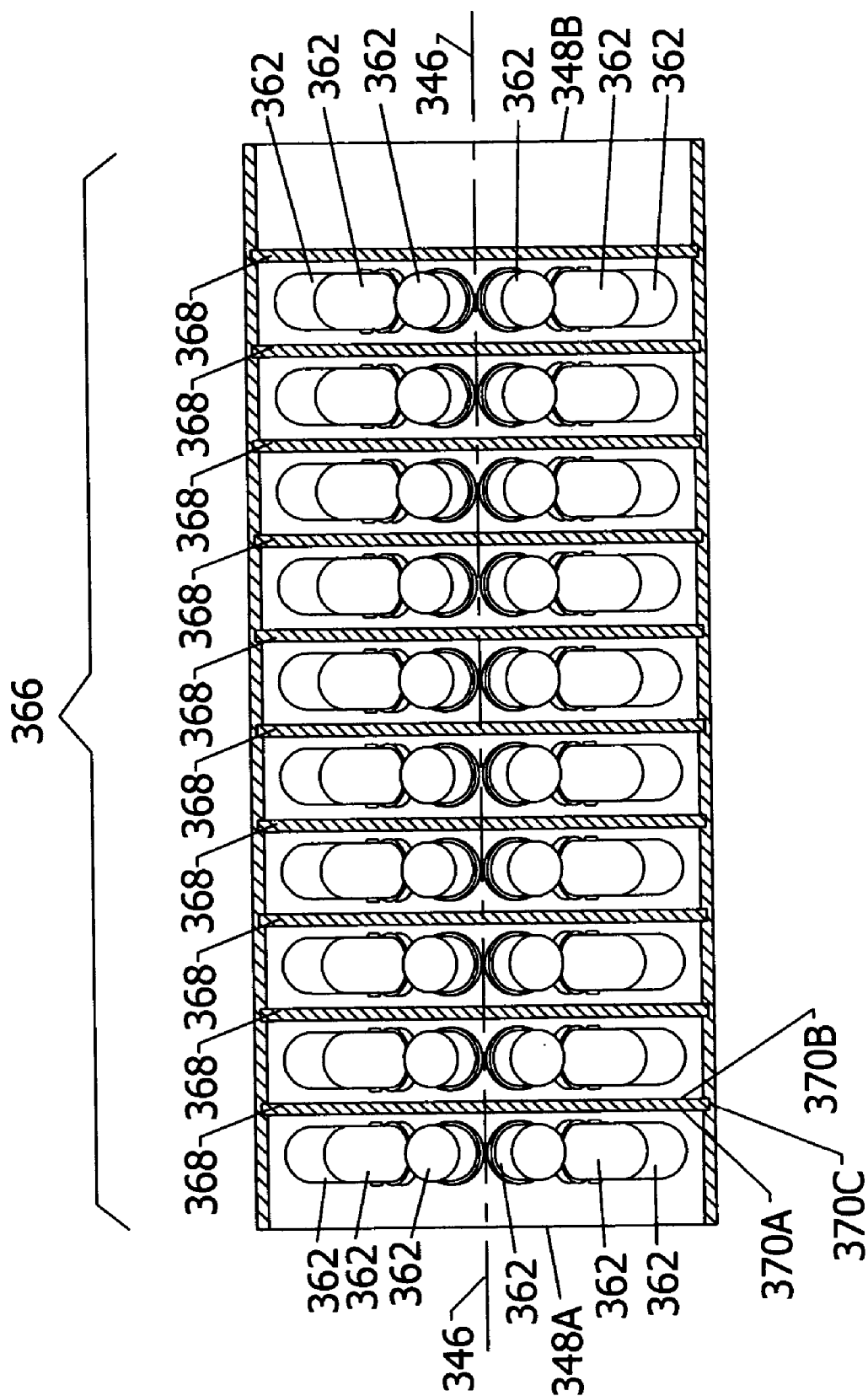


FIG. 29

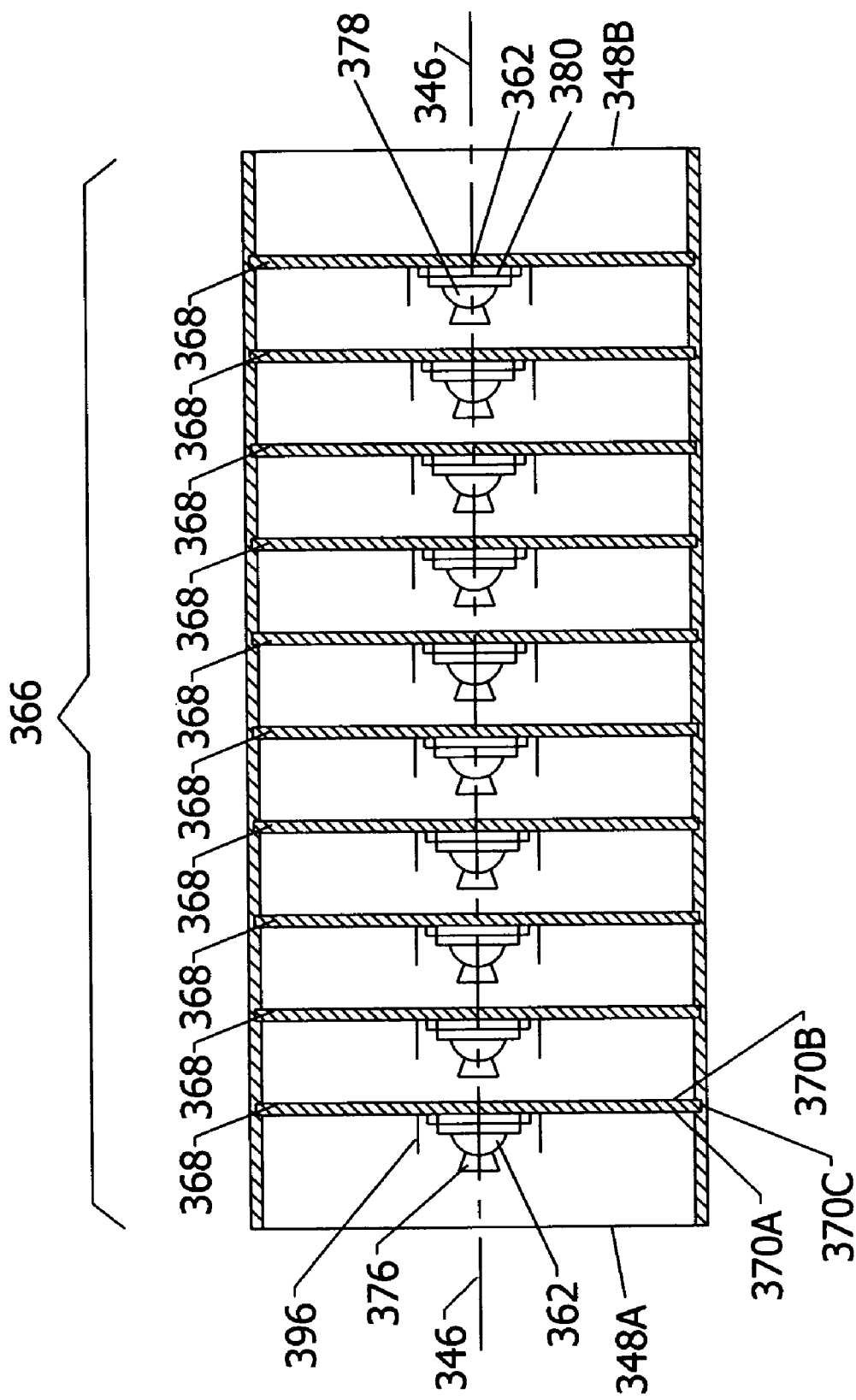


FIG. 29A

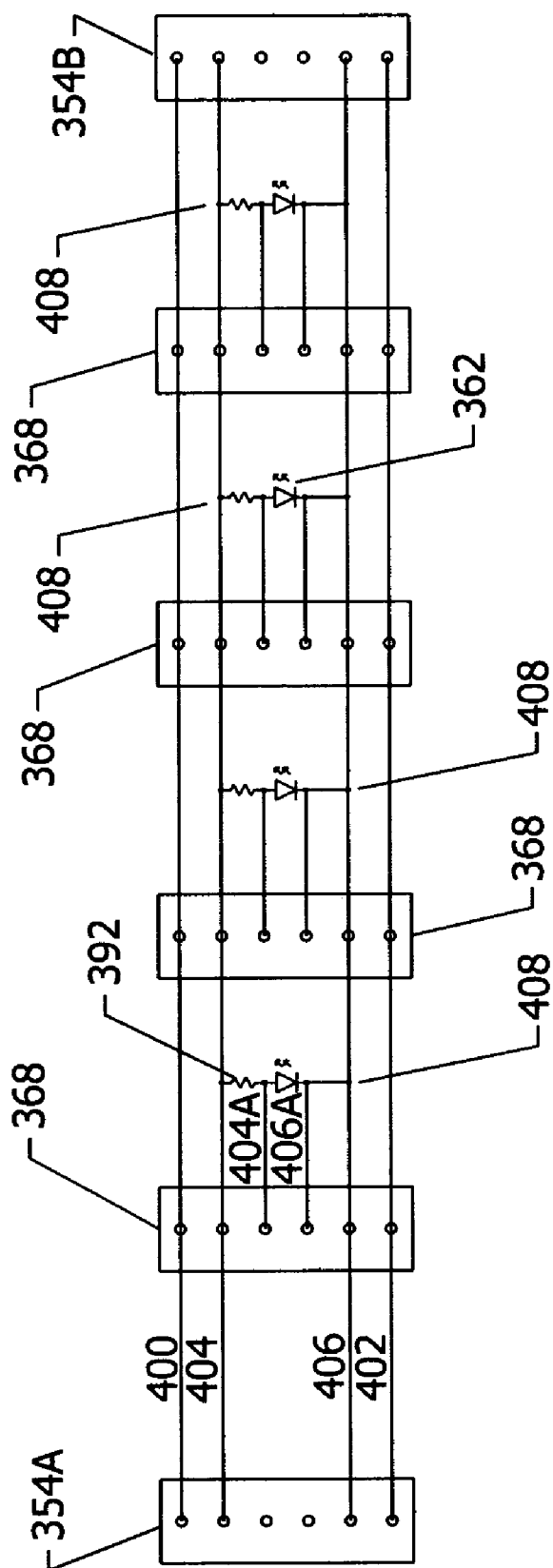


FIG. 29B

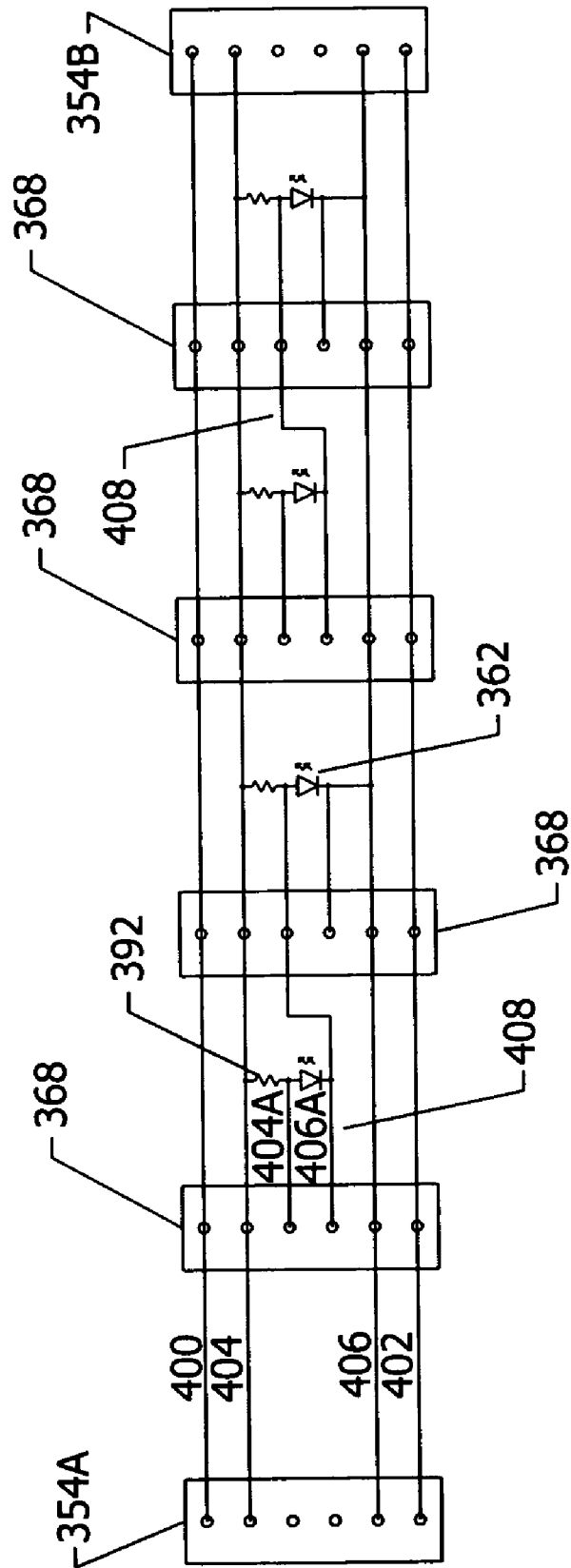


FIG. 29C

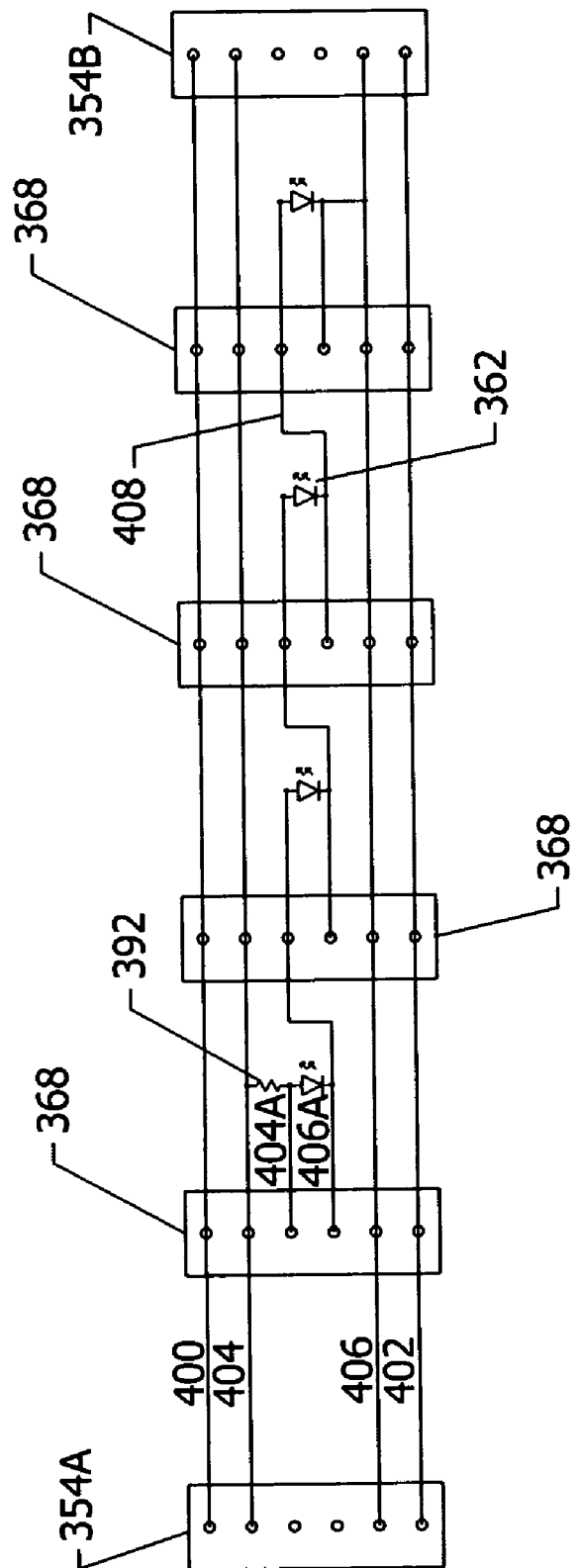


FIG. 29D

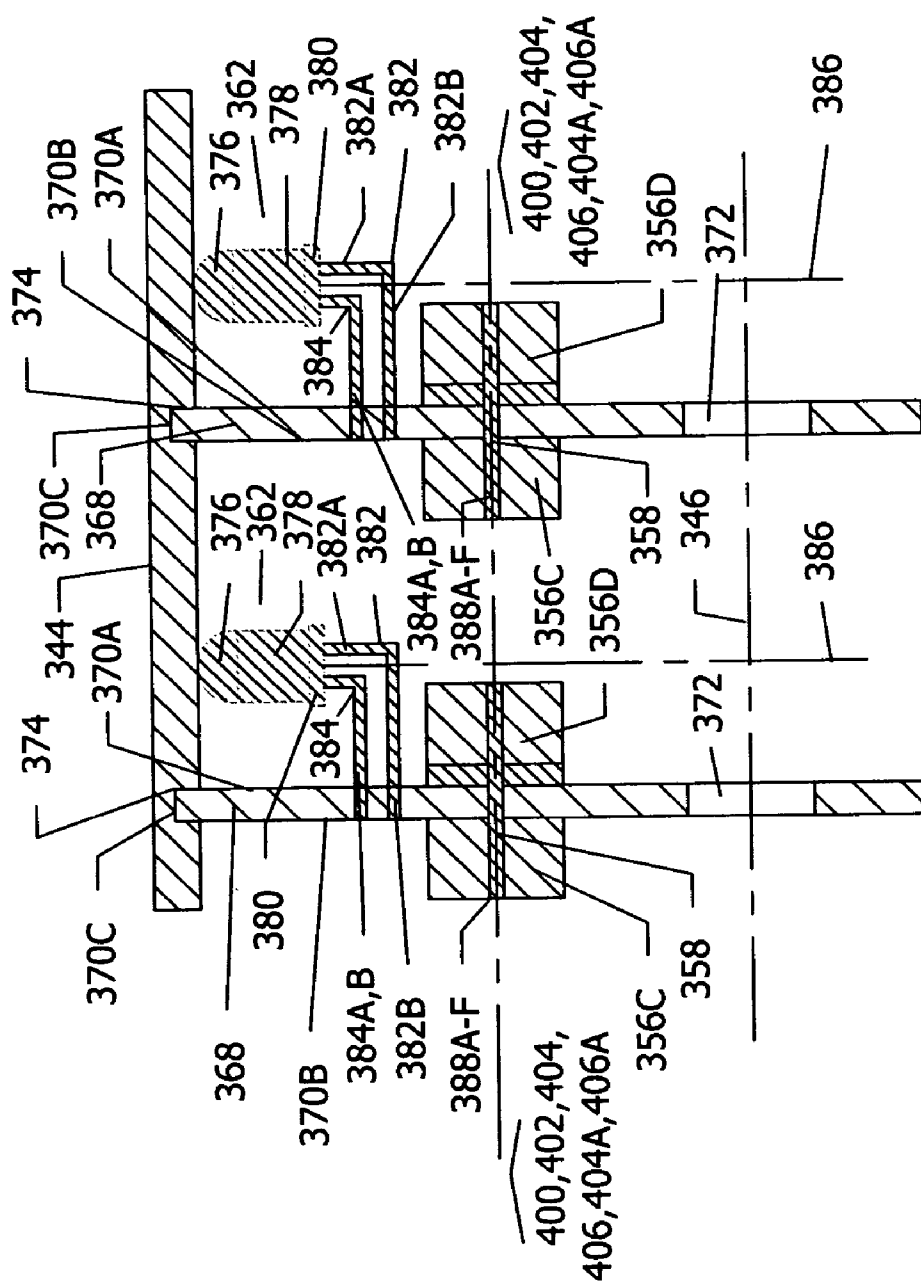


FIG. 30

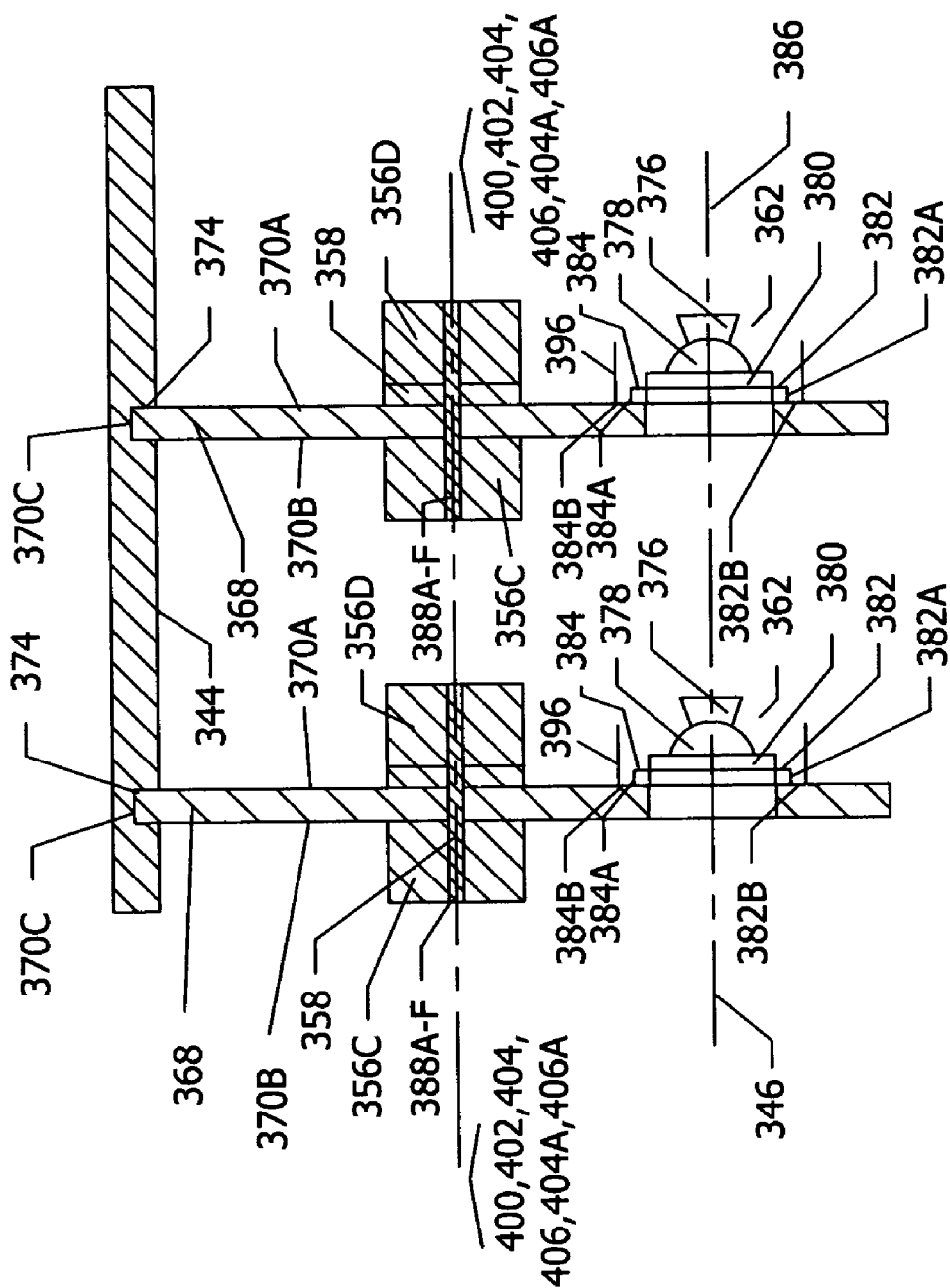


FIG. 30A

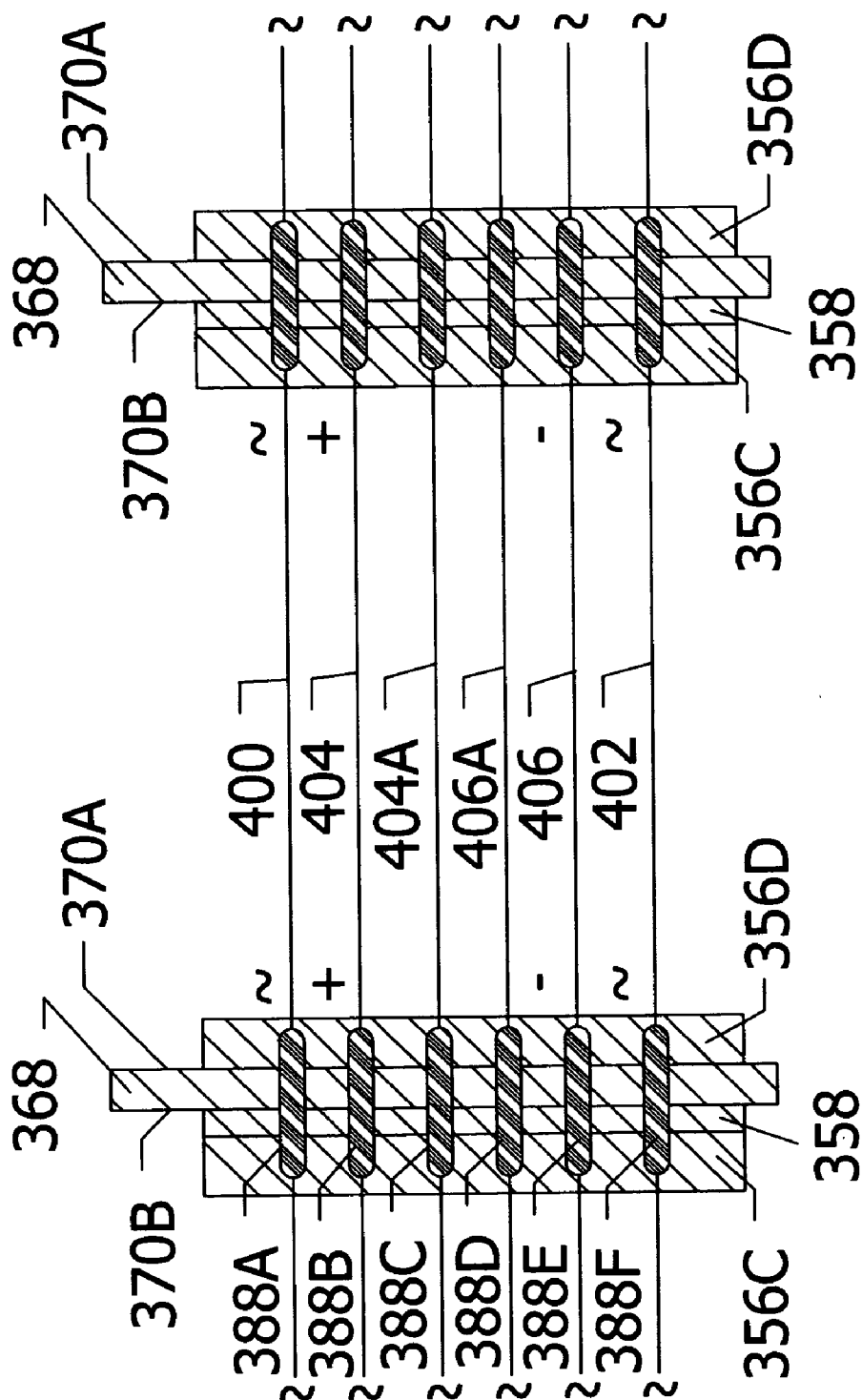
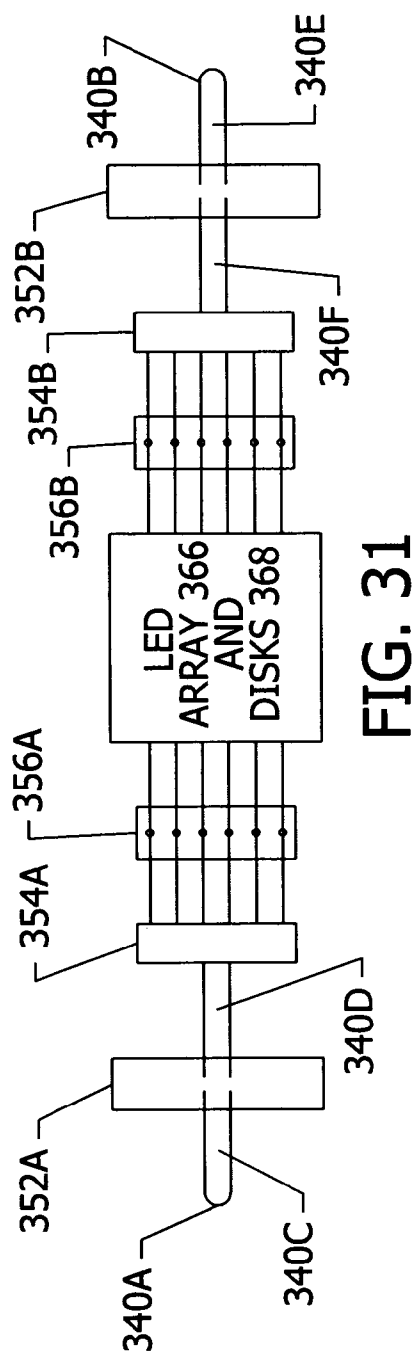
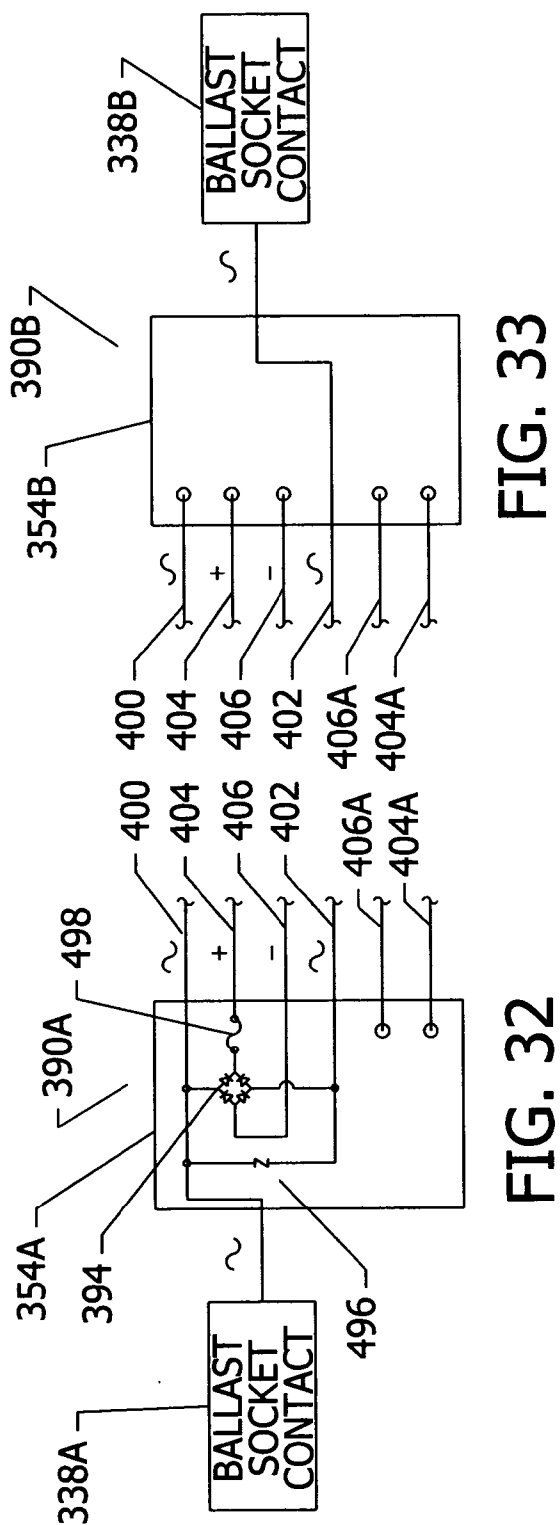


FIG. 30B



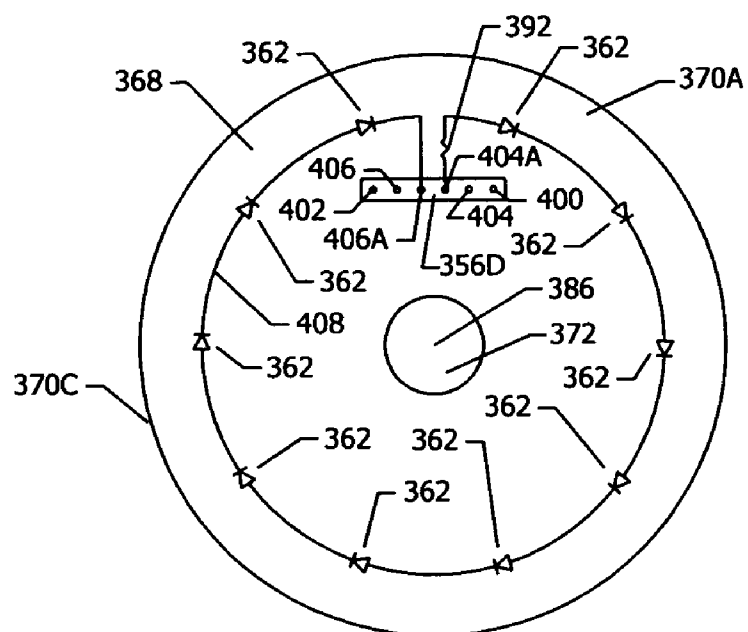


FIG. 34

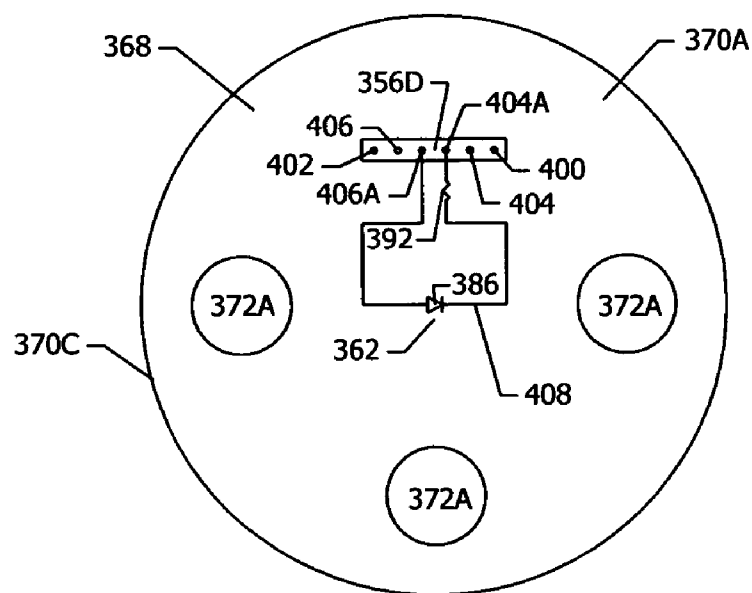


FIG. 34A

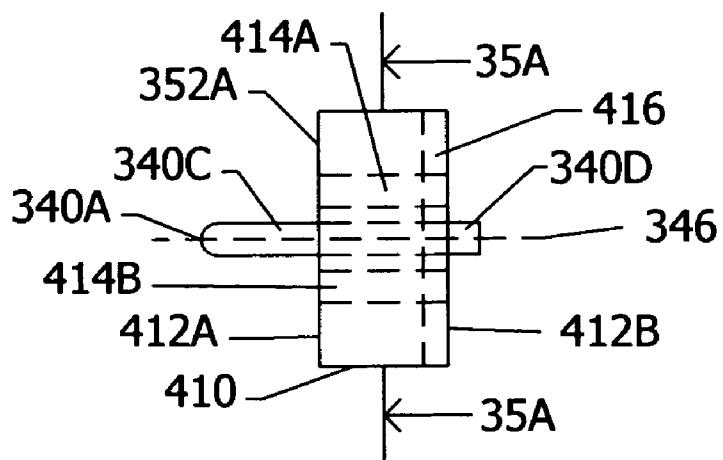


FIG. 35

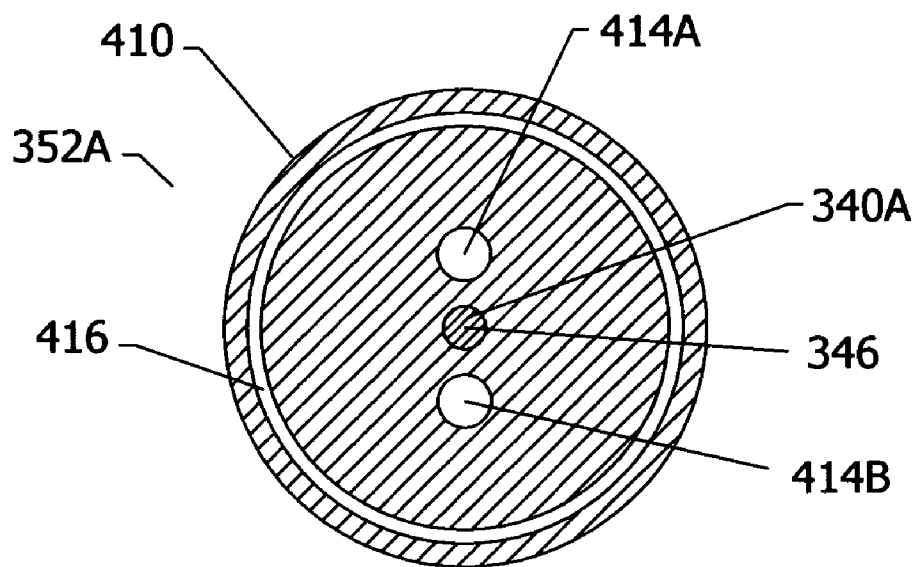


FIG. 35A

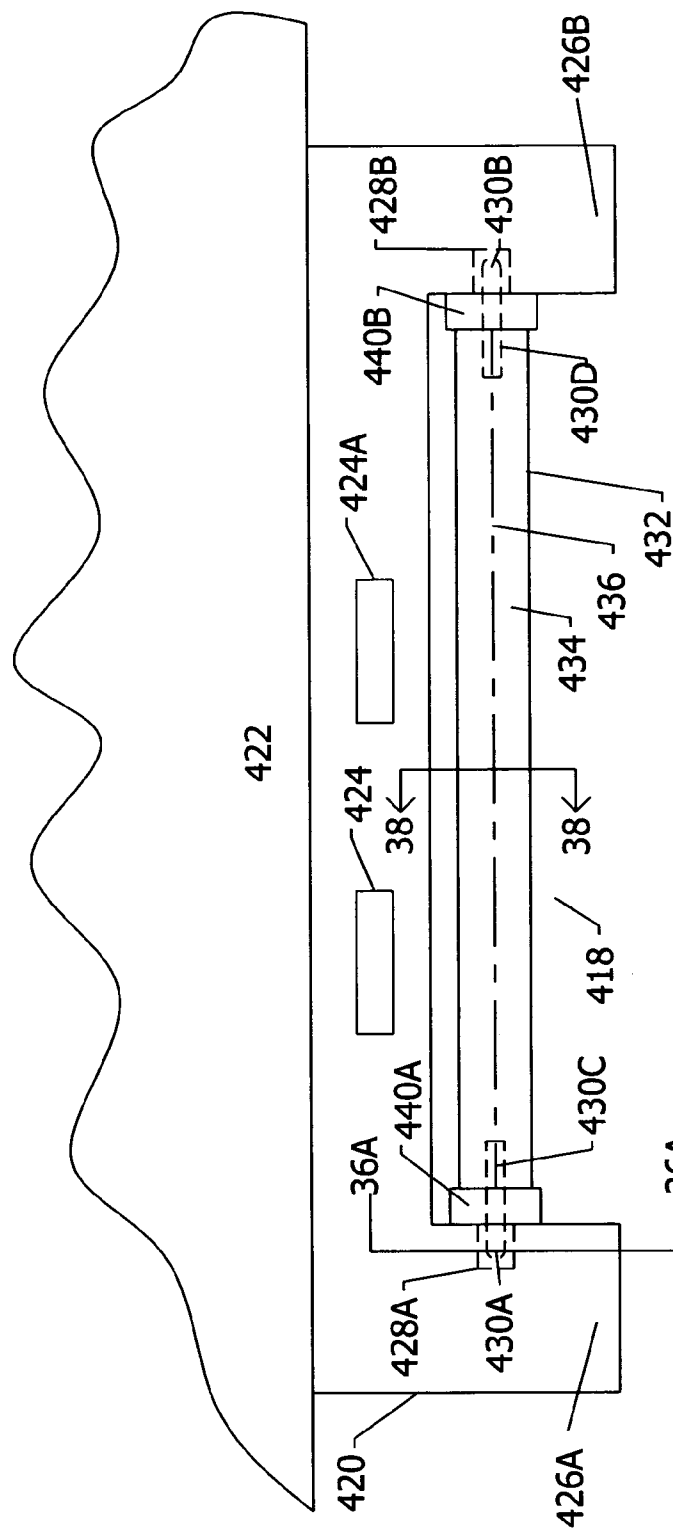


FIG. 36

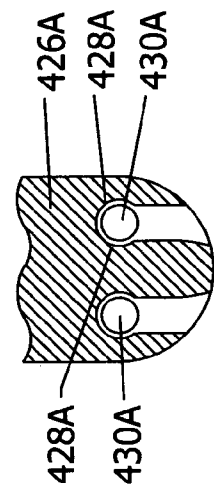


FIG. 36A

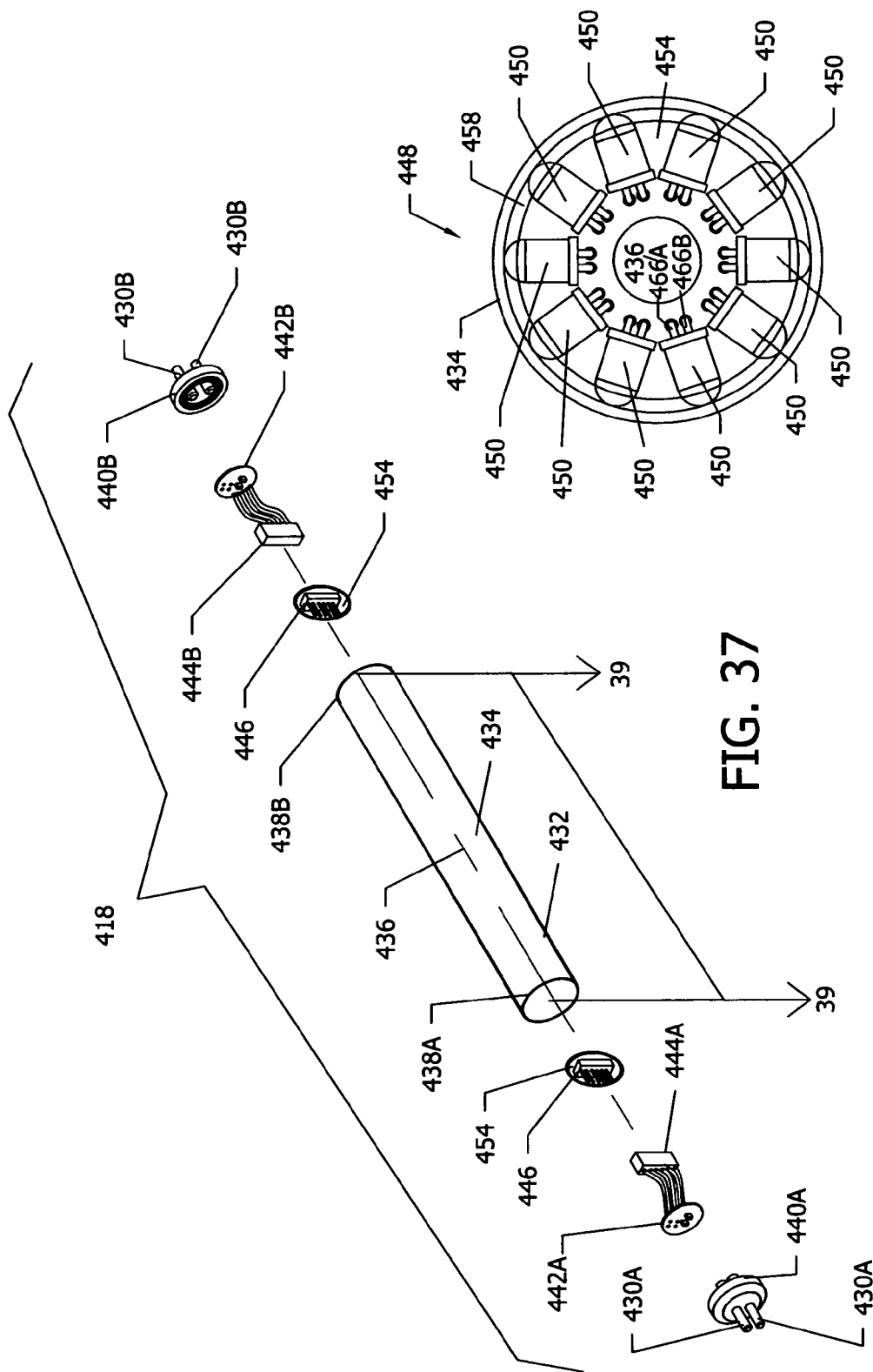


FIG. 38

FIG. 37

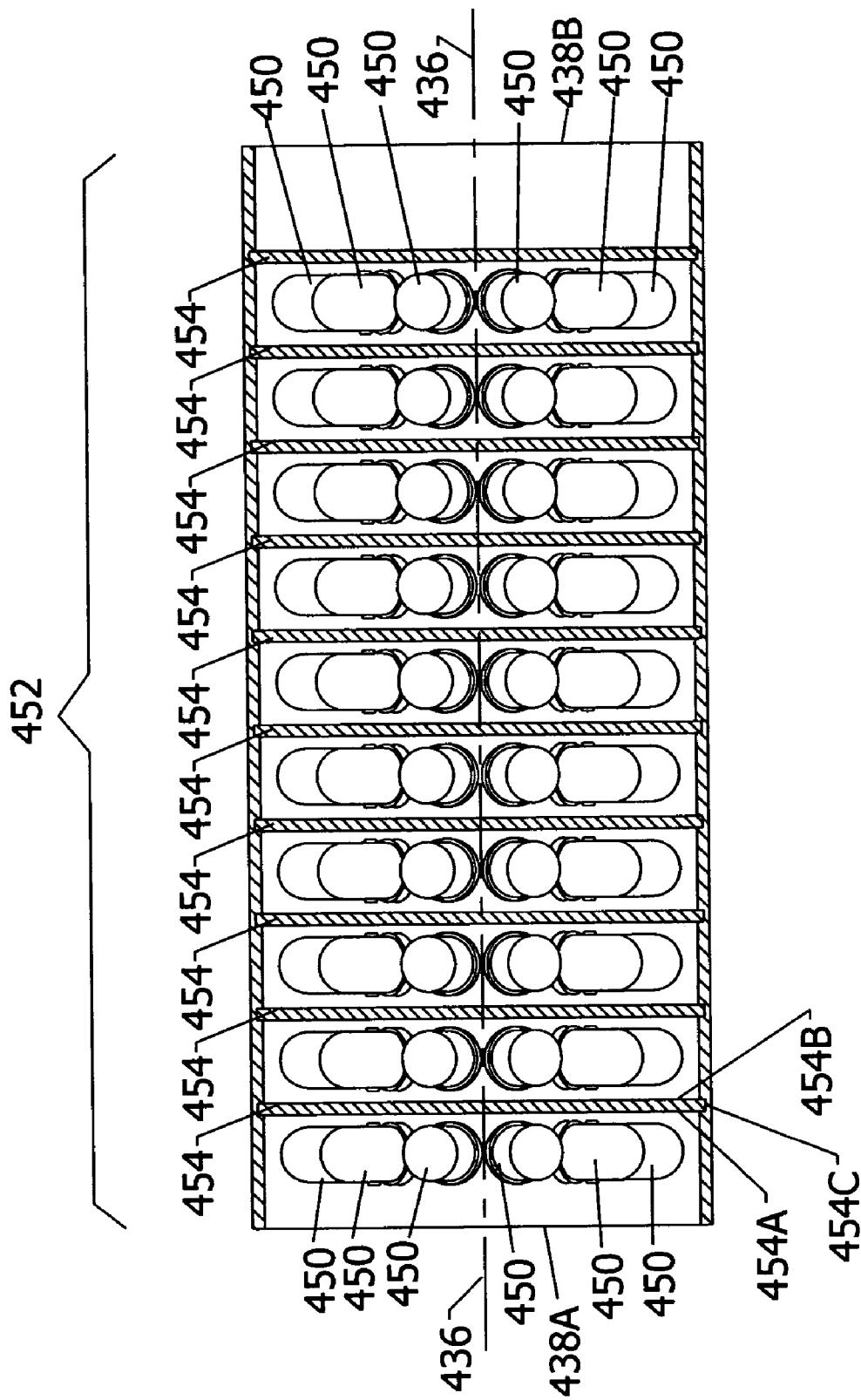


FIG. 39

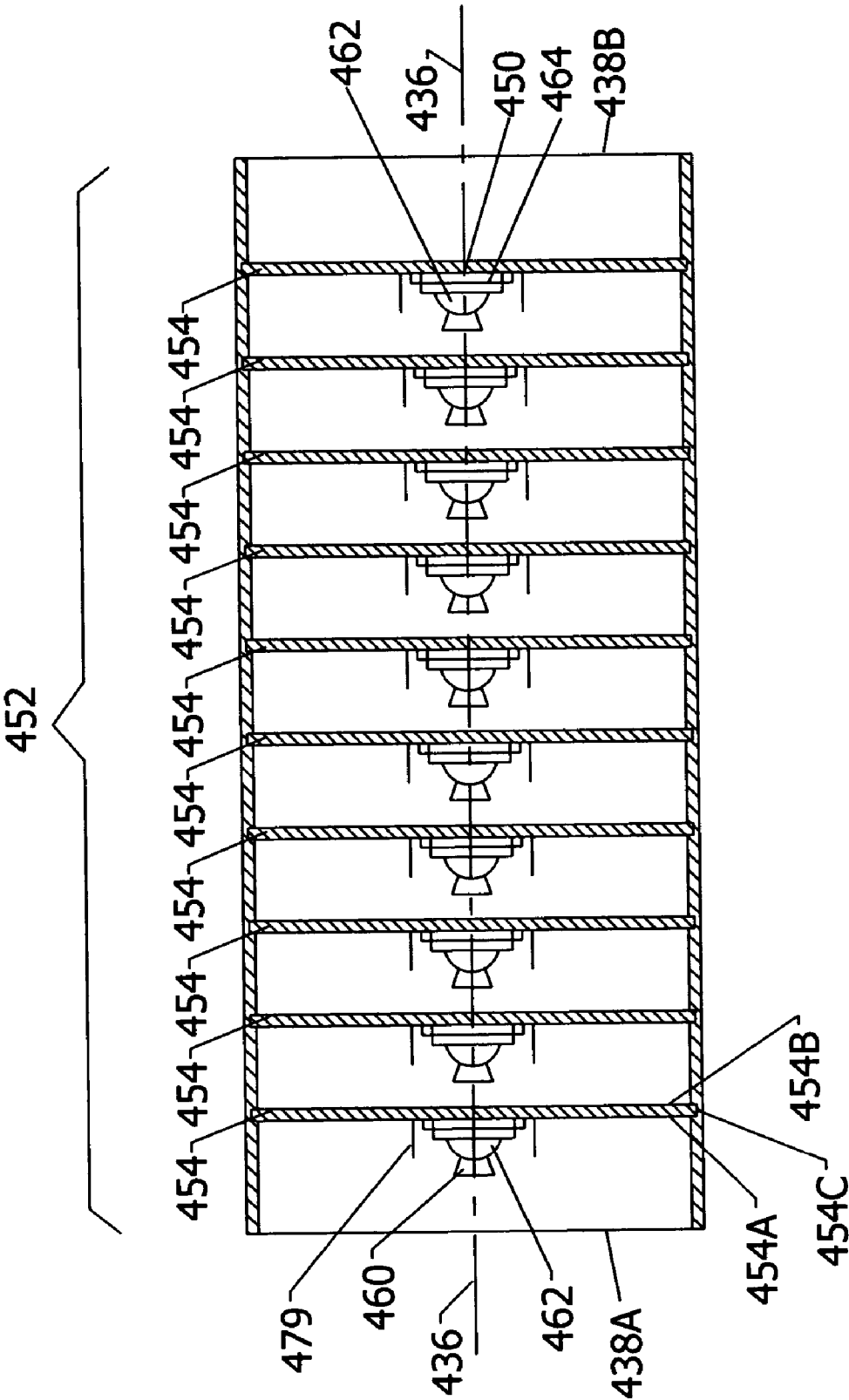


FIG. 39A

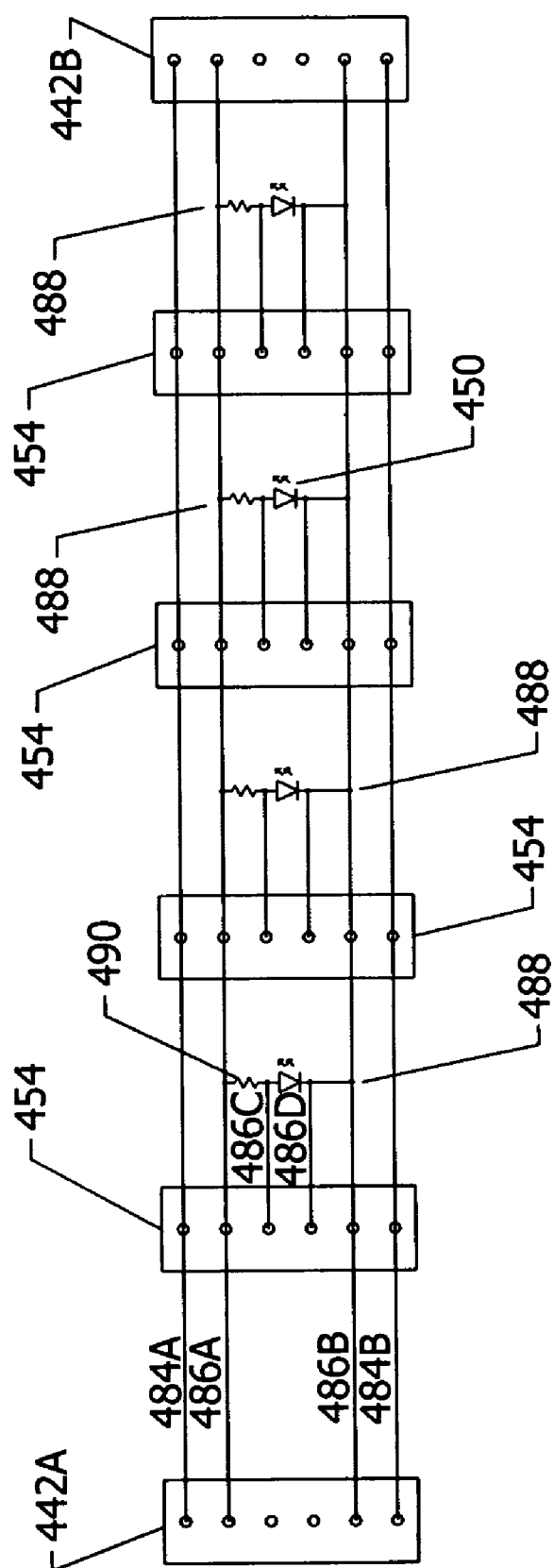


FIG. 39B

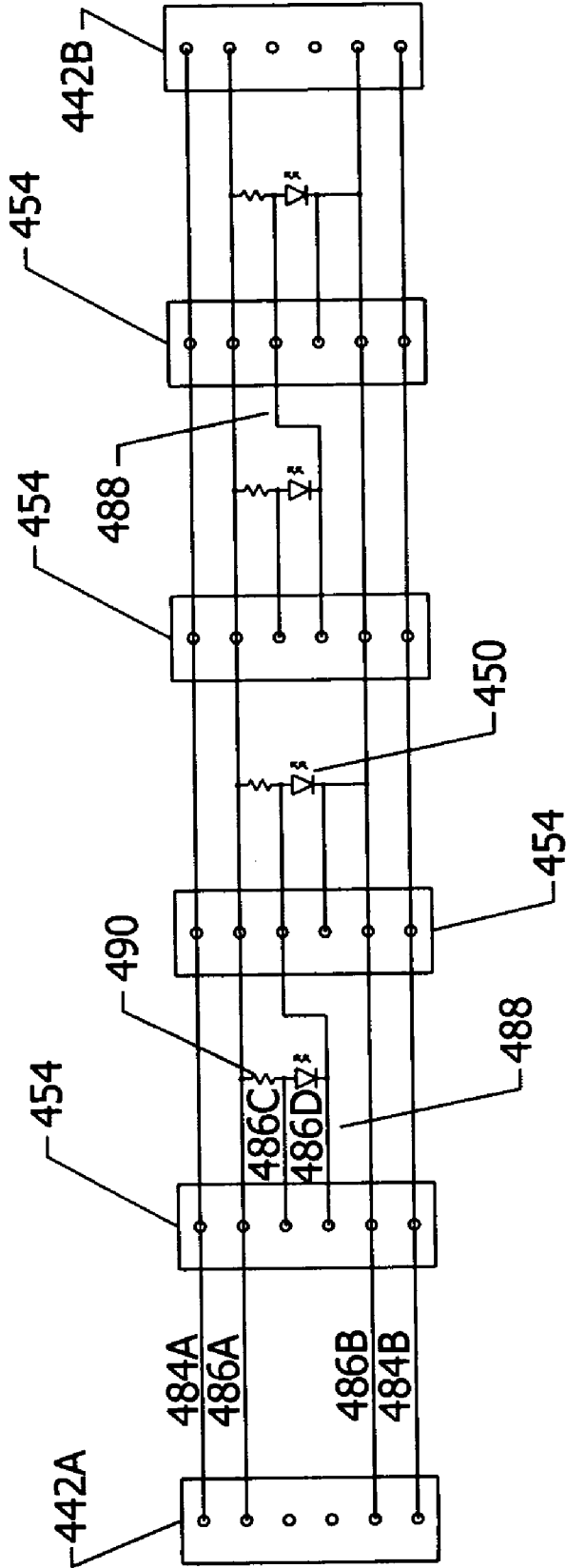


FIG. 39C

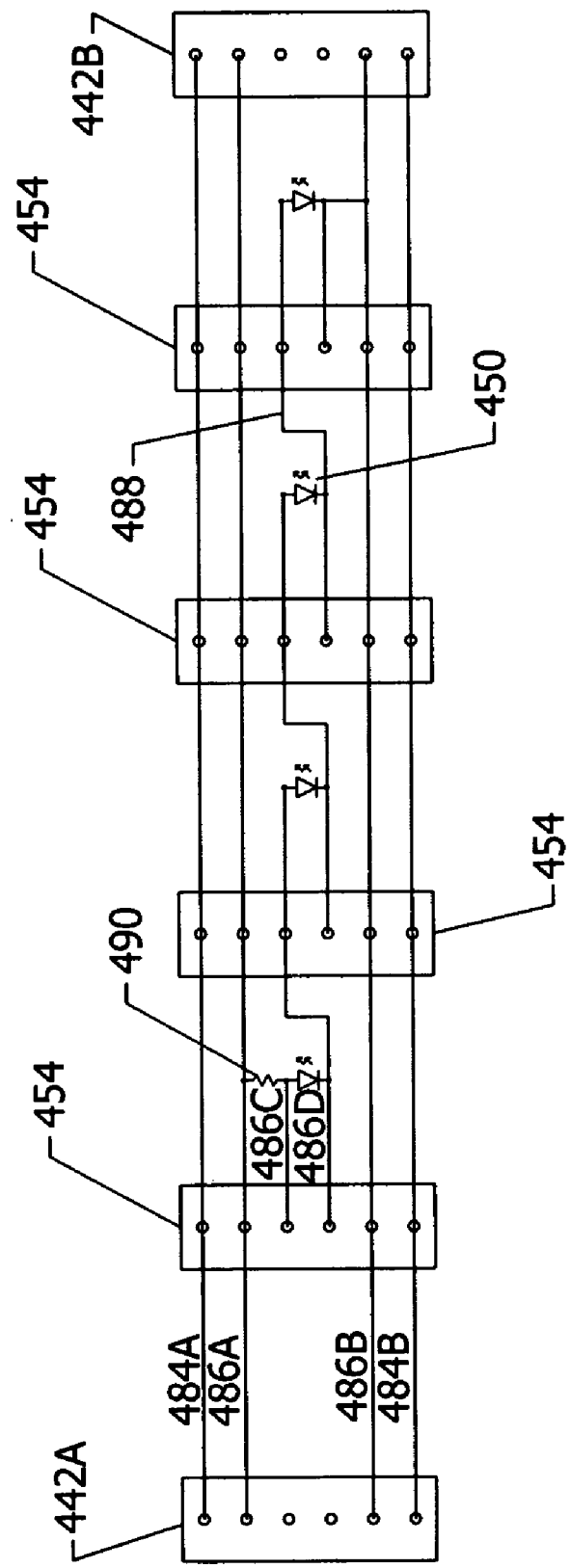


FIG. 39D

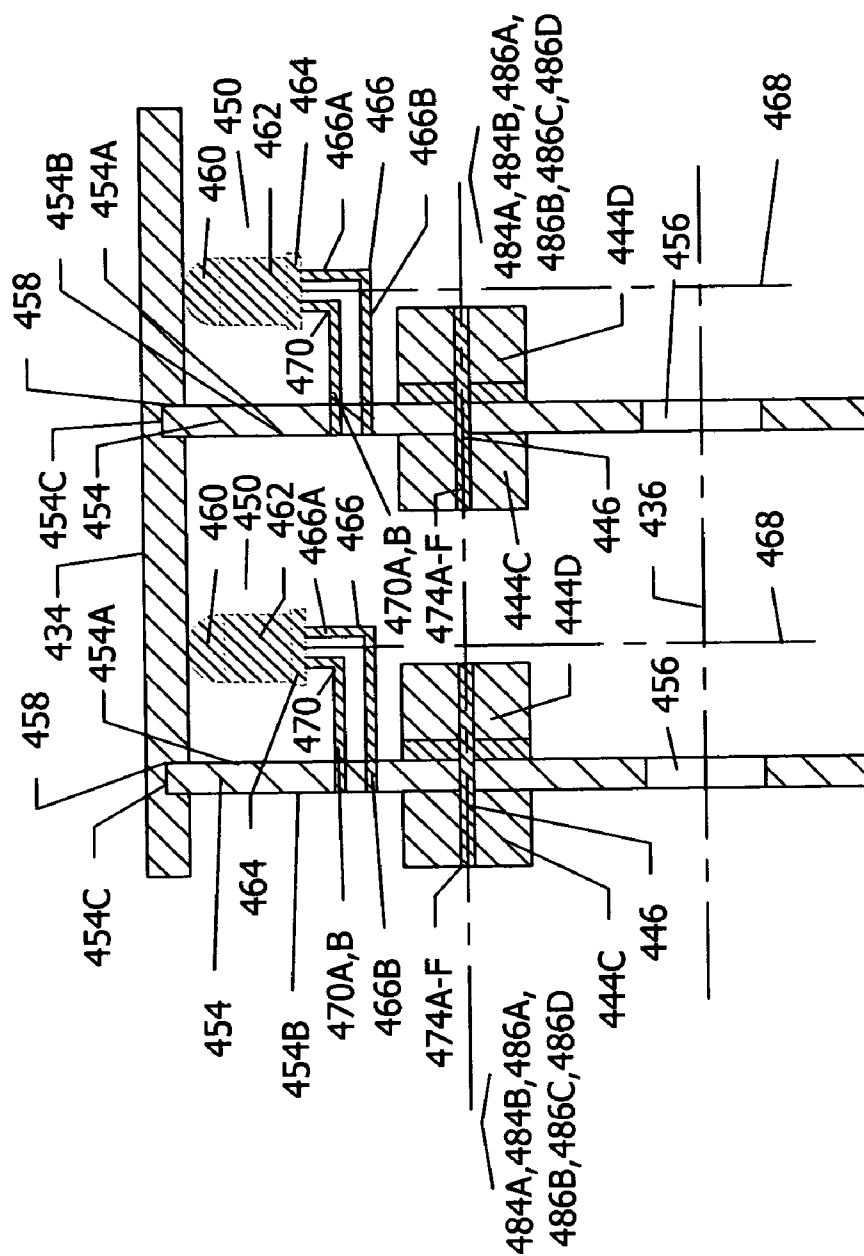


FIG. 40

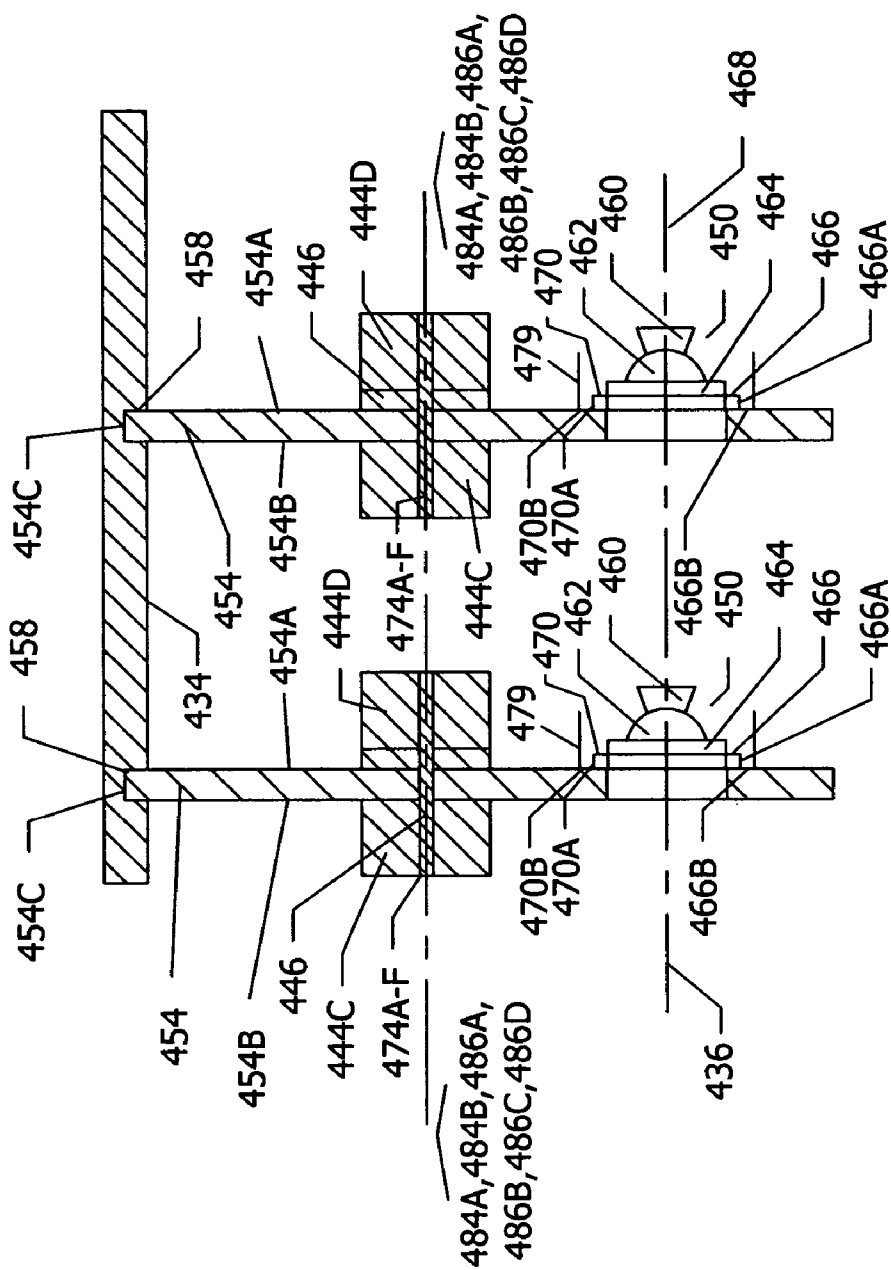


FIG. 40A

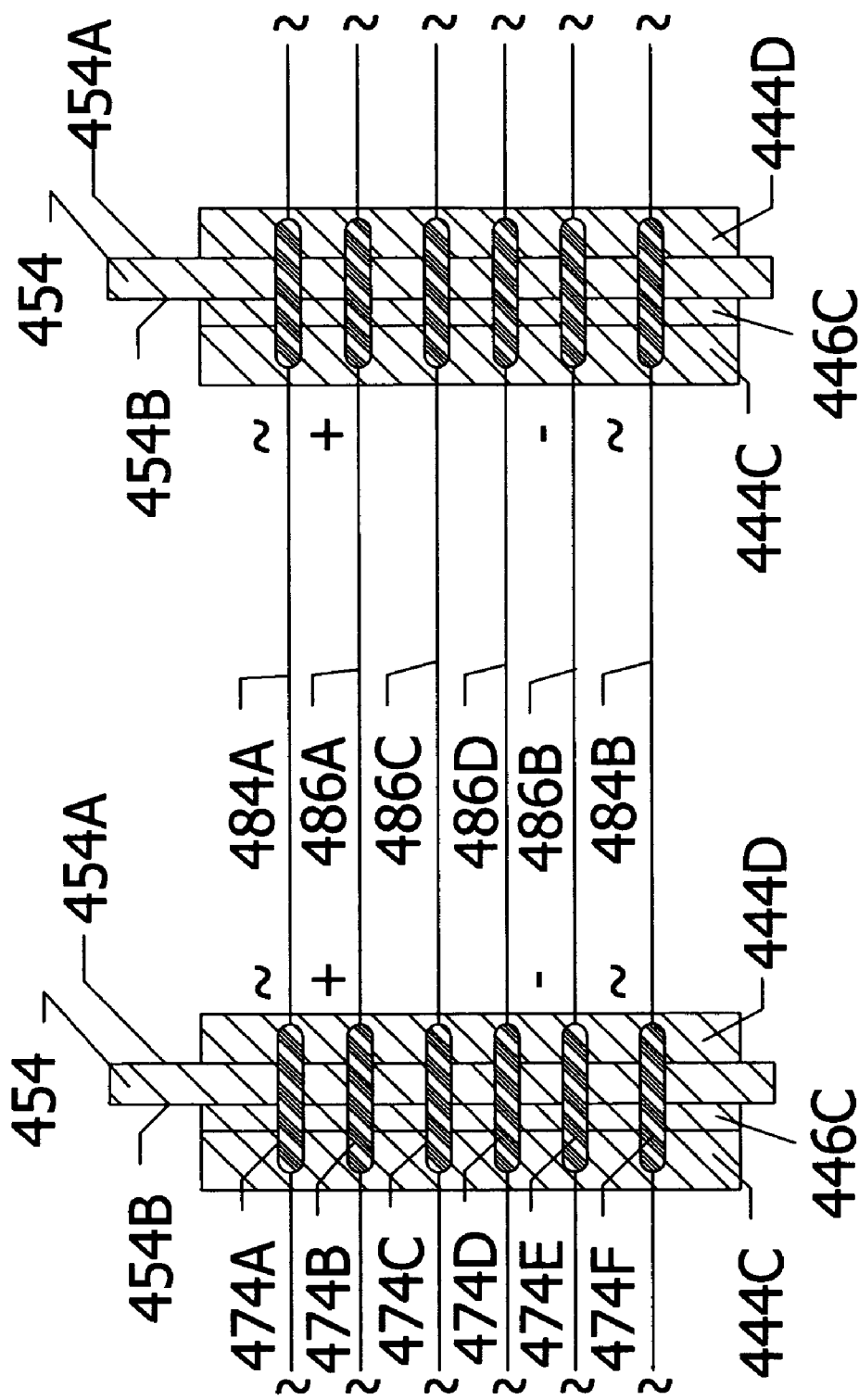
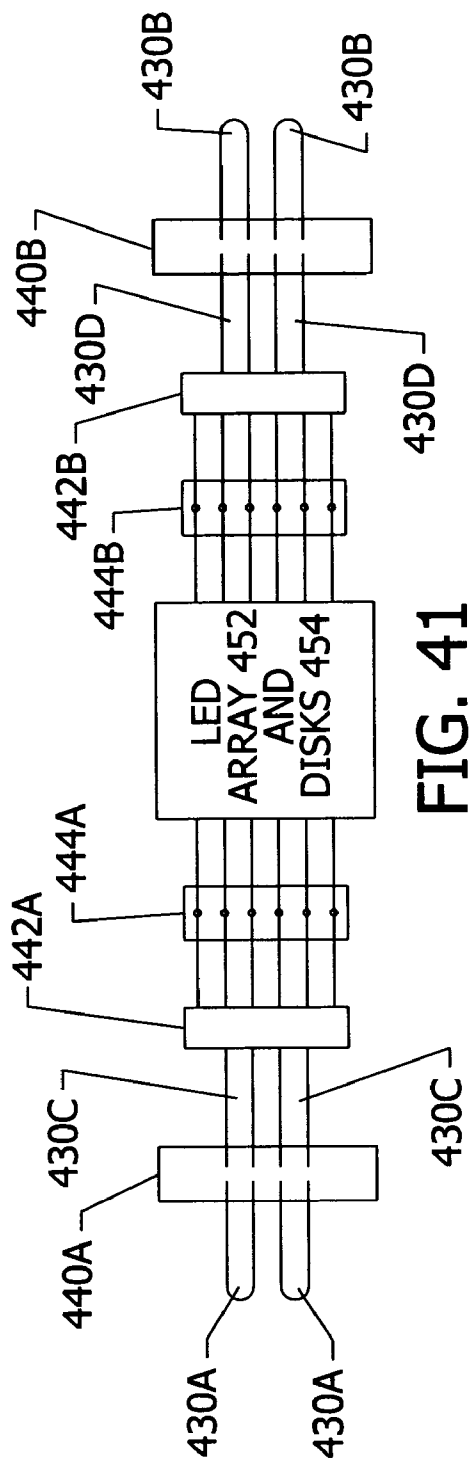
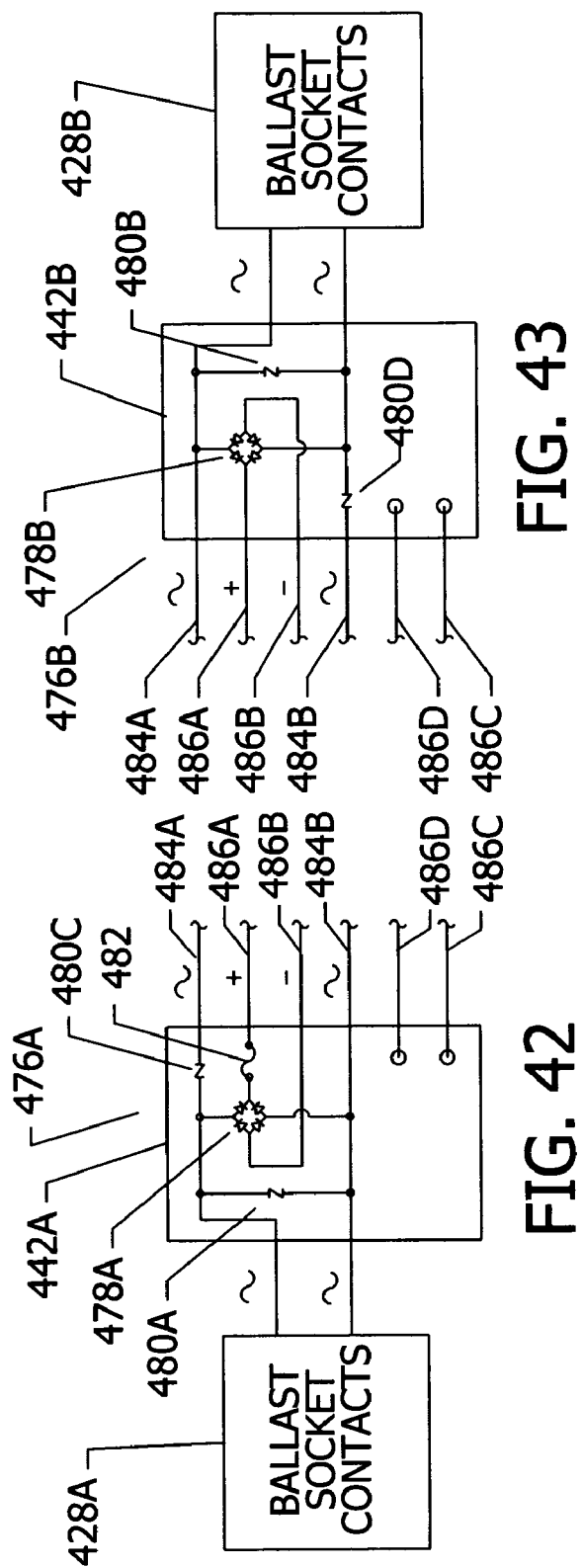


FIG. 40B



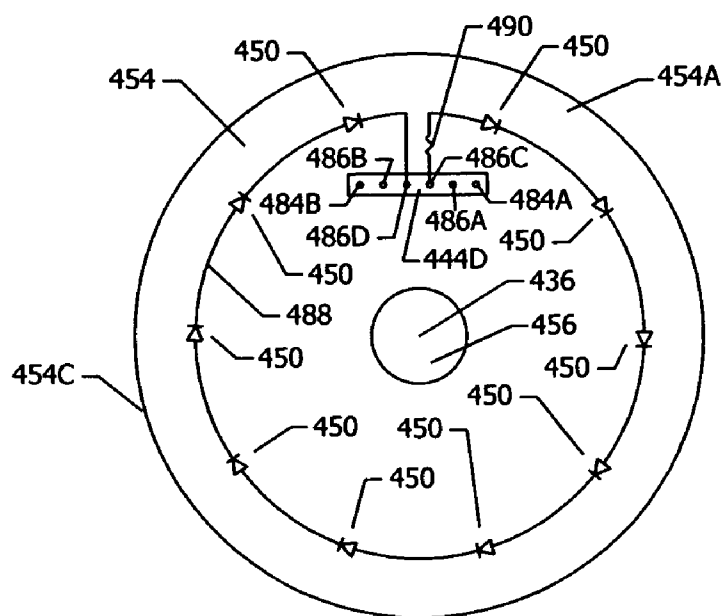


FIG. 44

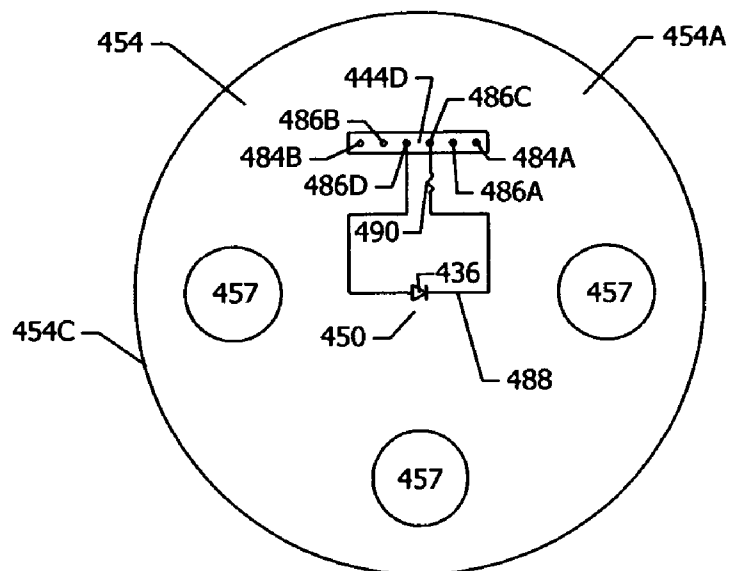


FIG. 44A

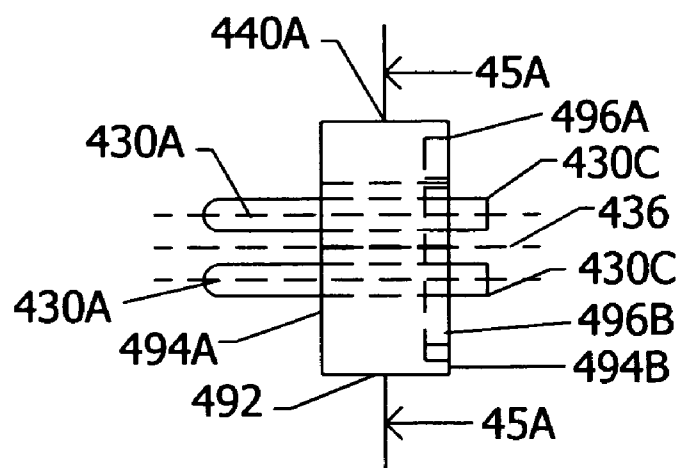


FIG. 45

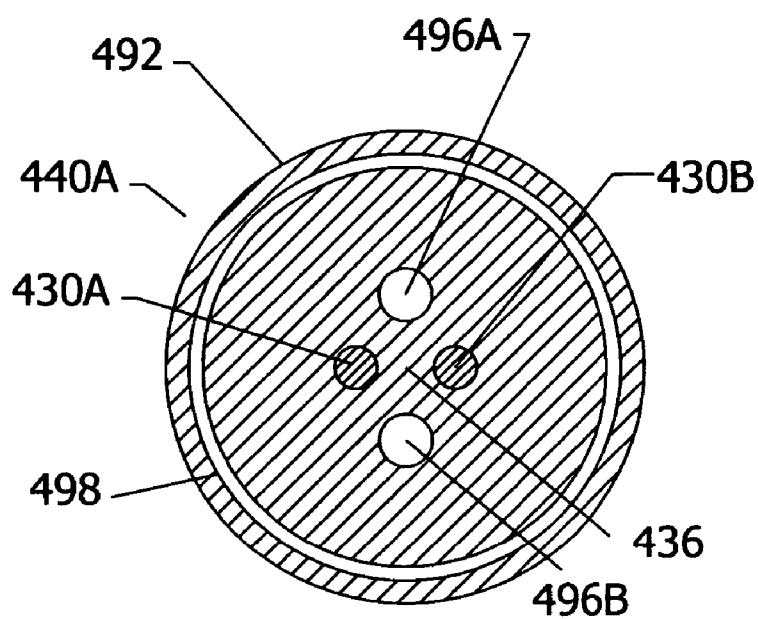


FIG. 45A

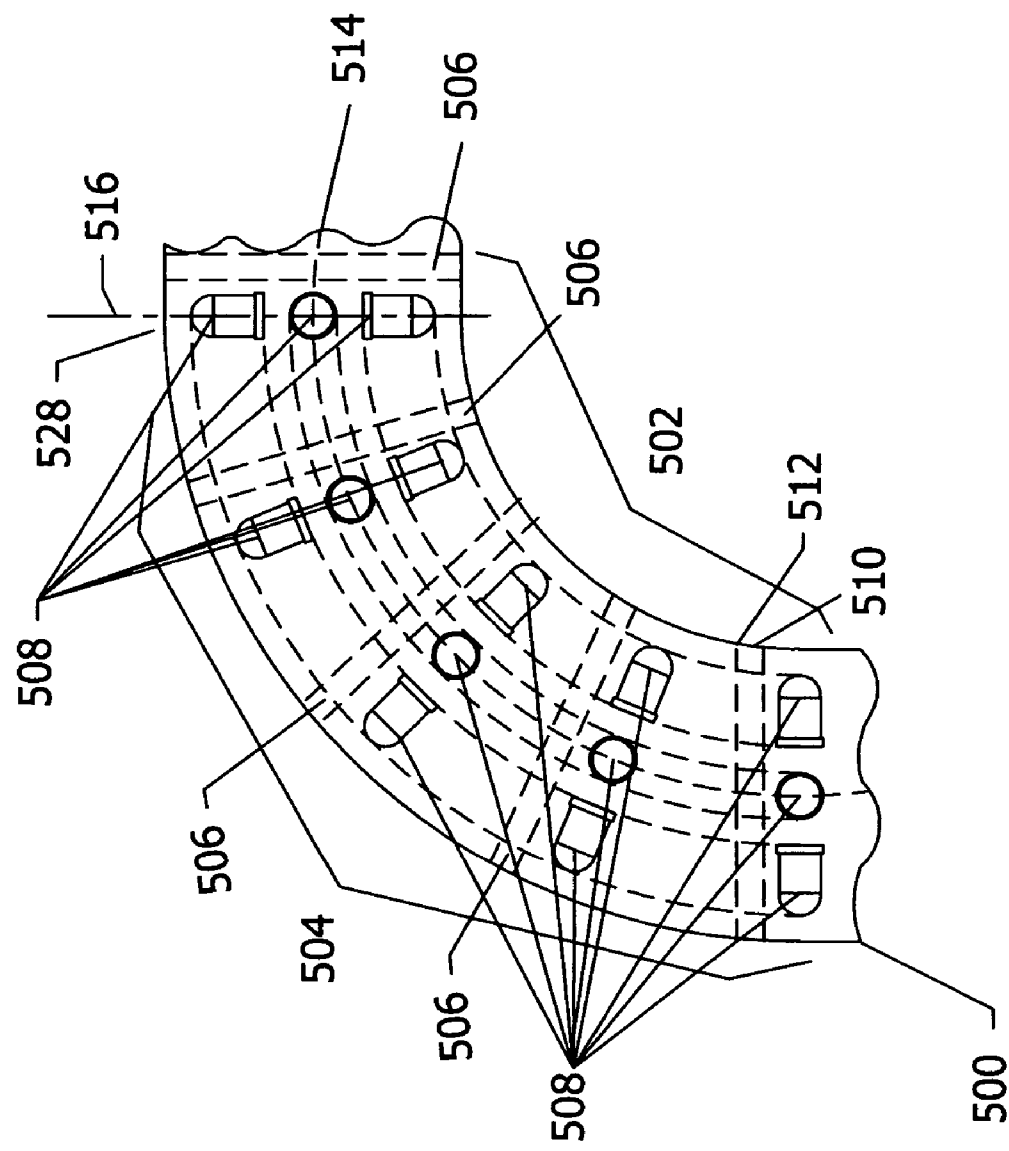


FIG 46

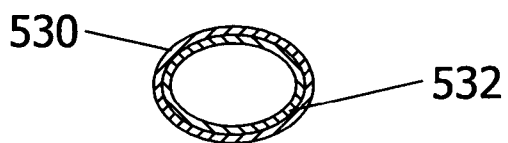


FIG. 47

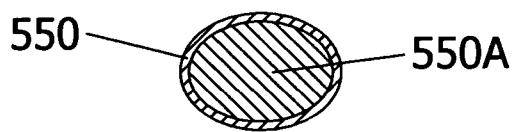


FIG. 48

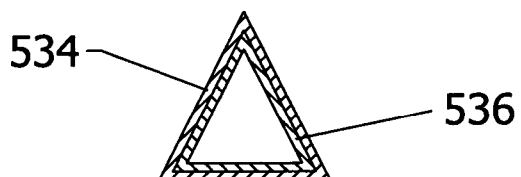


FIG. 47A

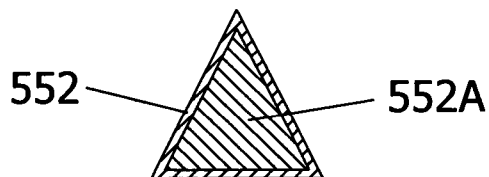


FIG. 48A

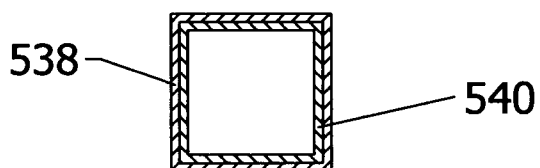


FIG. 47B

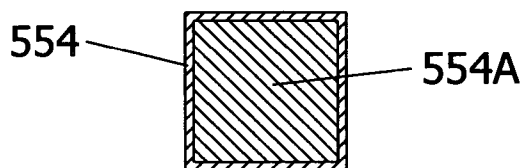


FIG. 48B

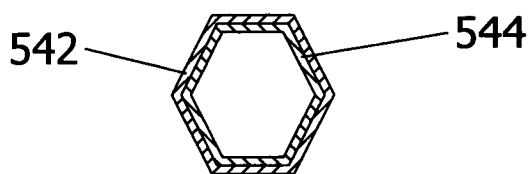


FIG. 47C

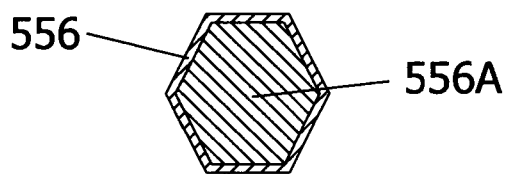


FIG. 48C

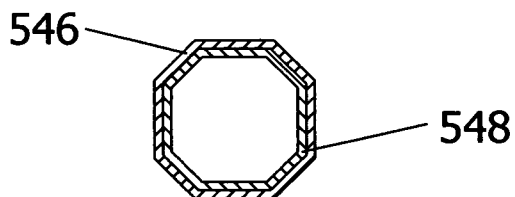


FIG. 47D

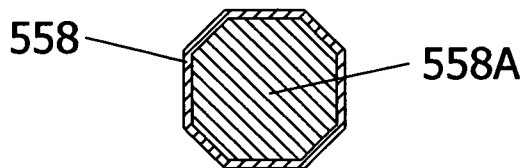


FIG. 48D

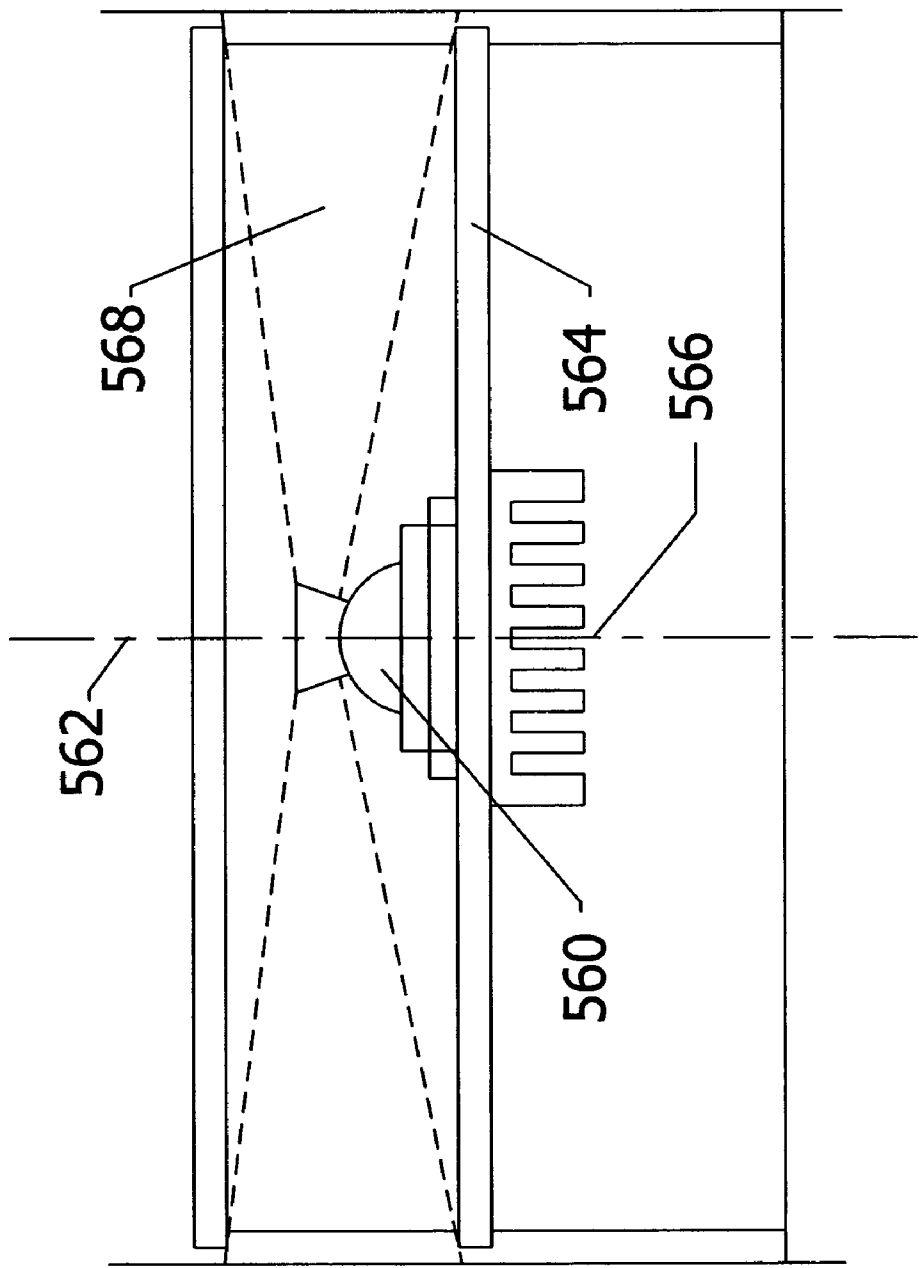
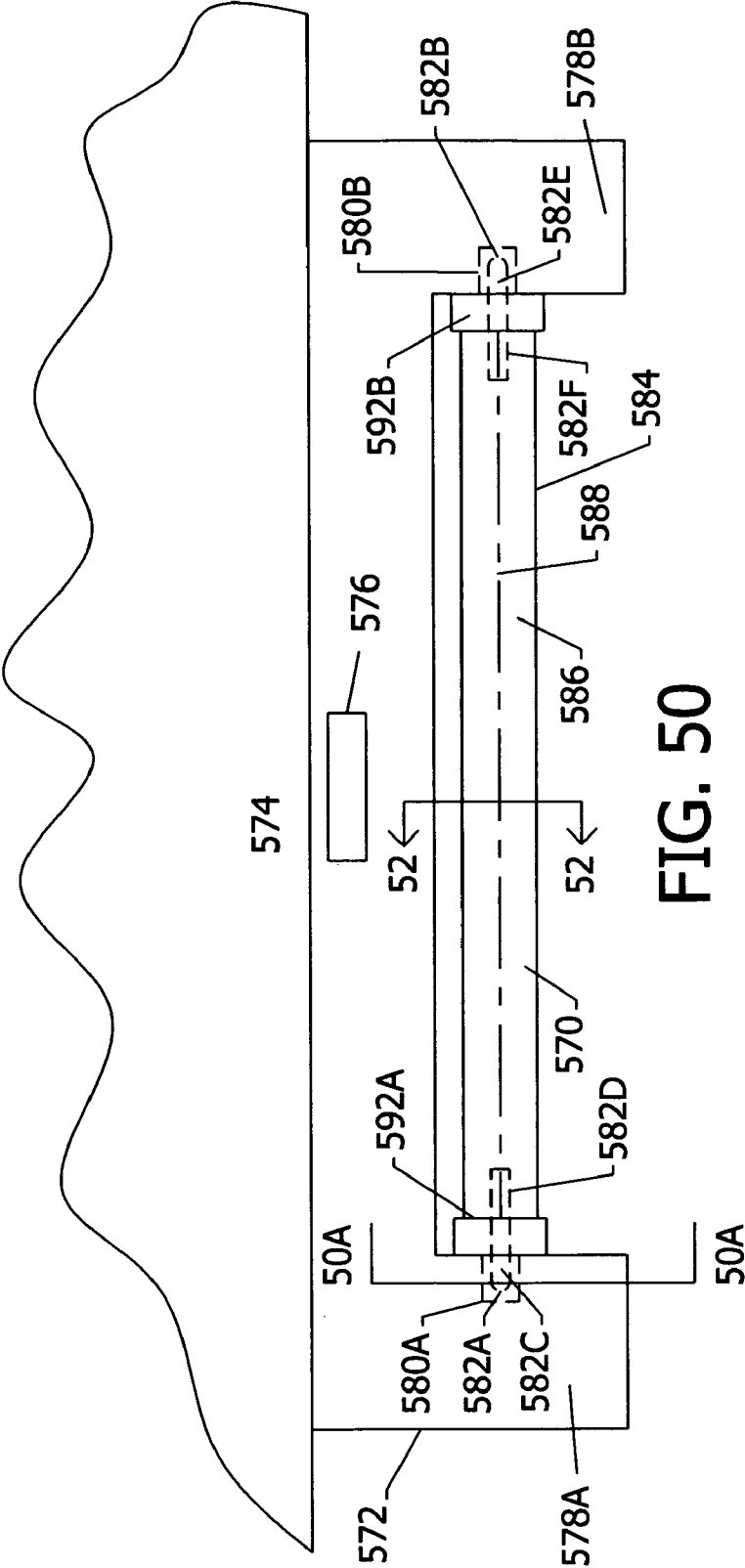
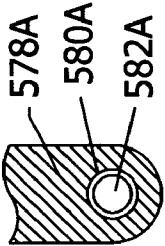
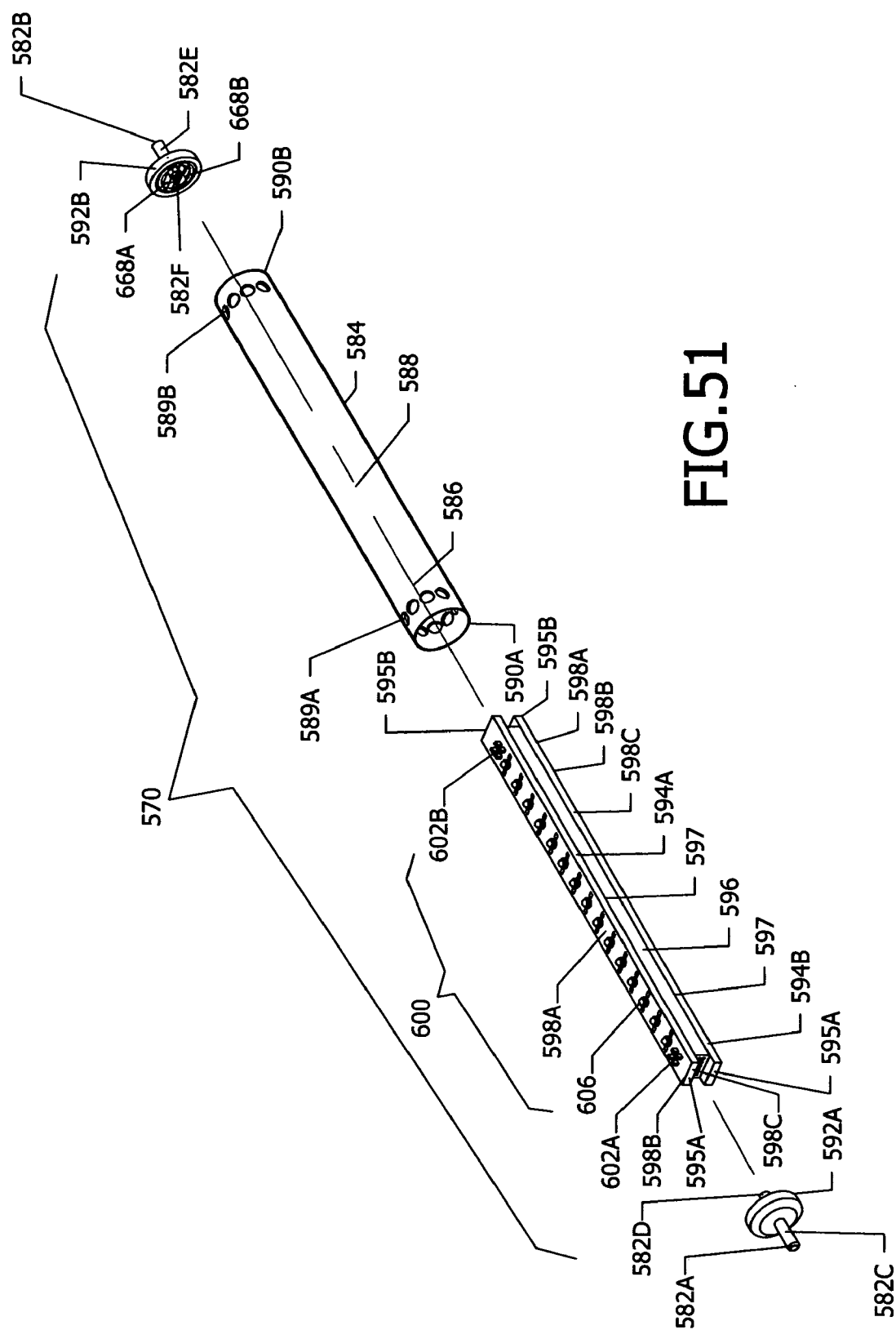


FIG. 49





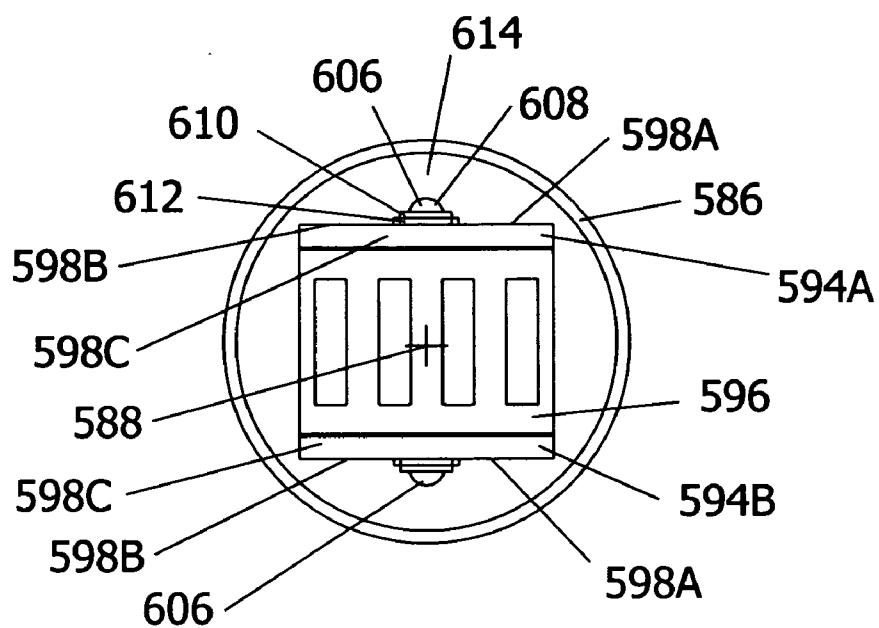


FIG. 52

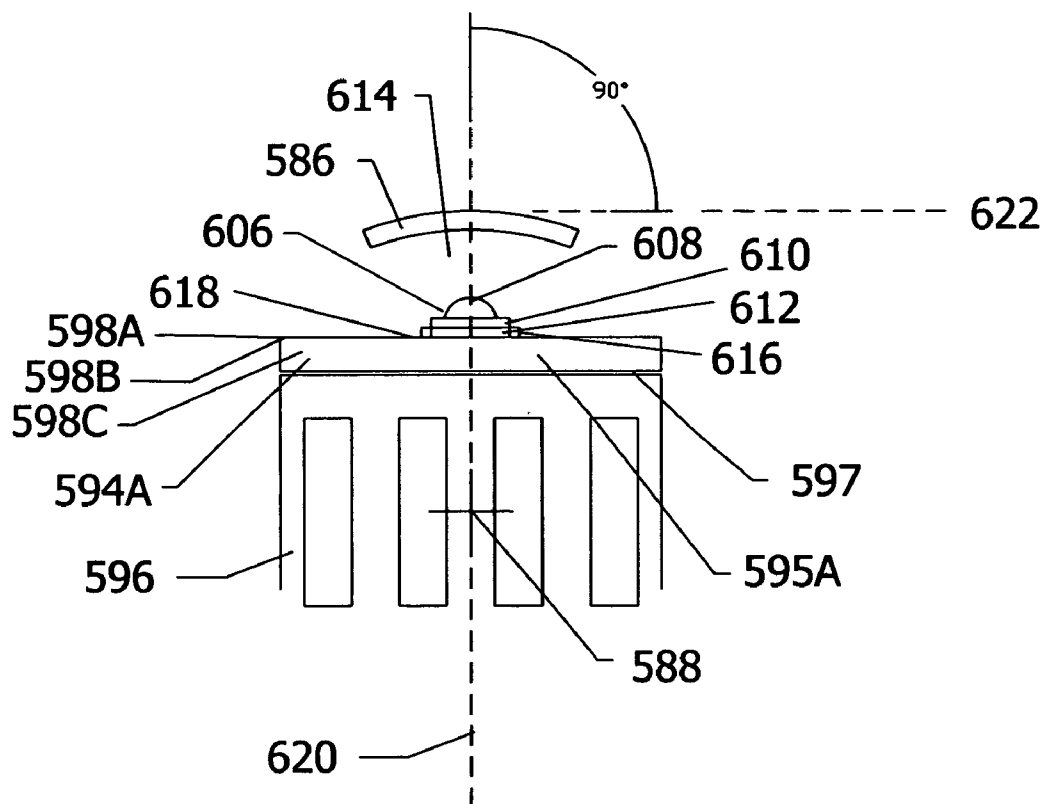


FIG. 52A

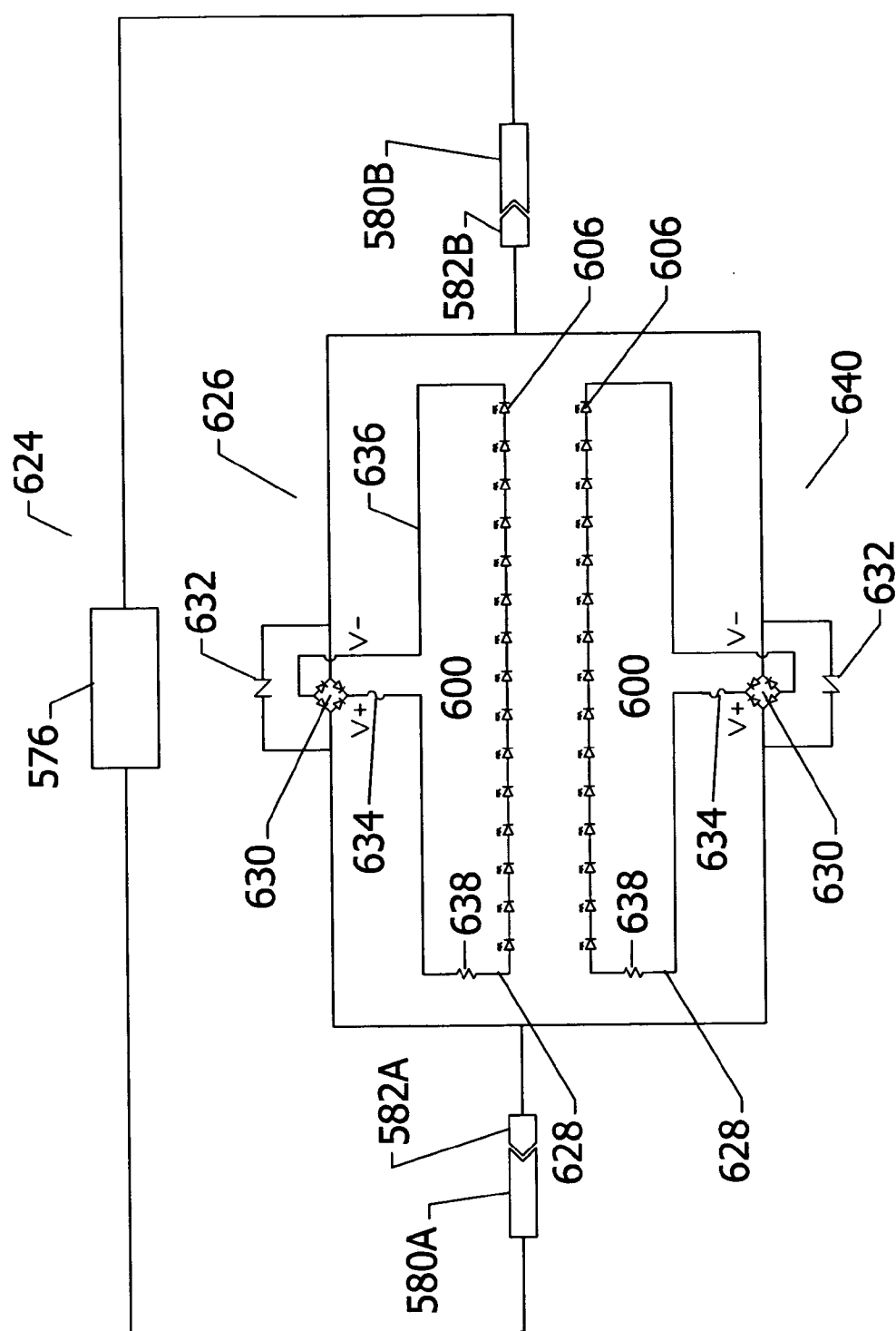


FIG. 53

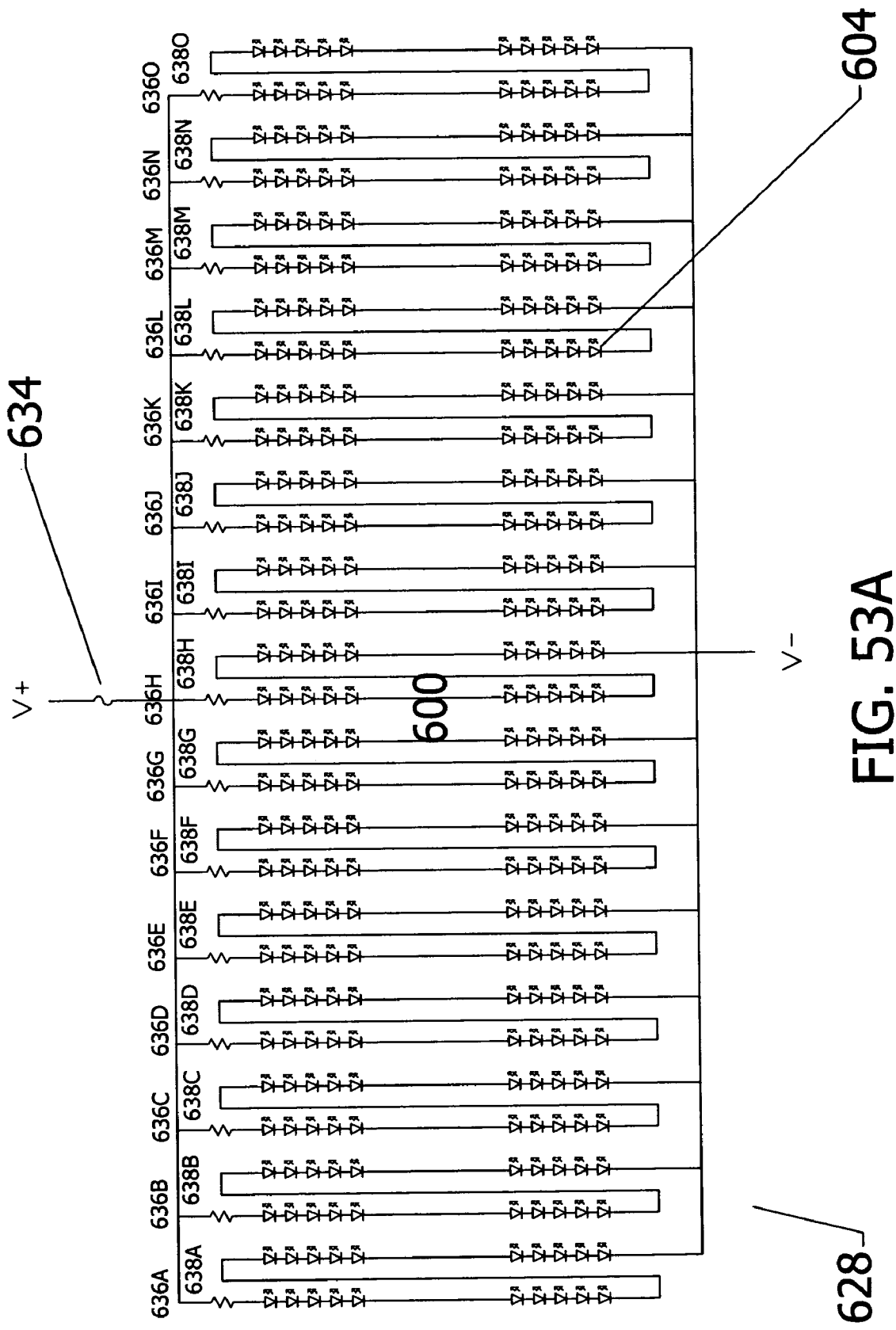


FIG. 53A

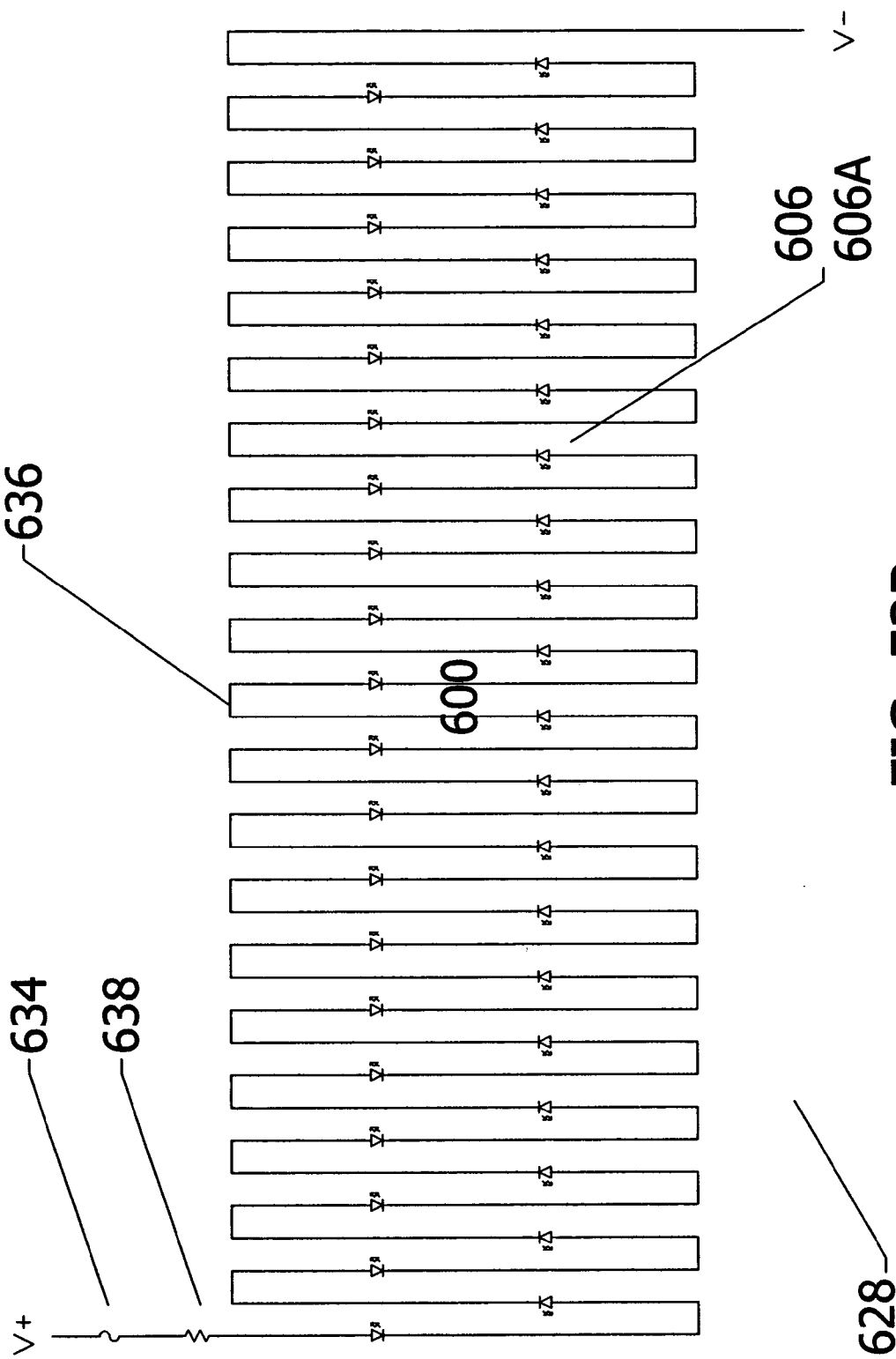


FIG. 53B

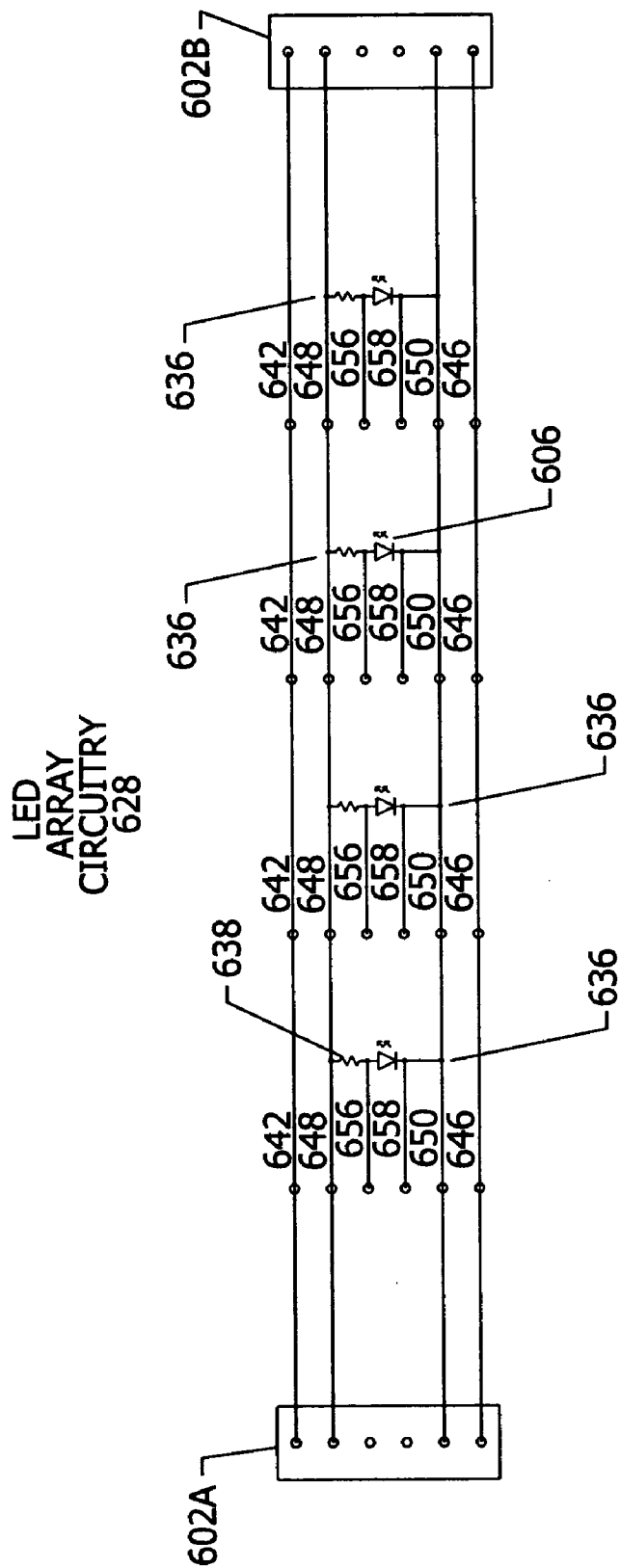


FIG. 53C

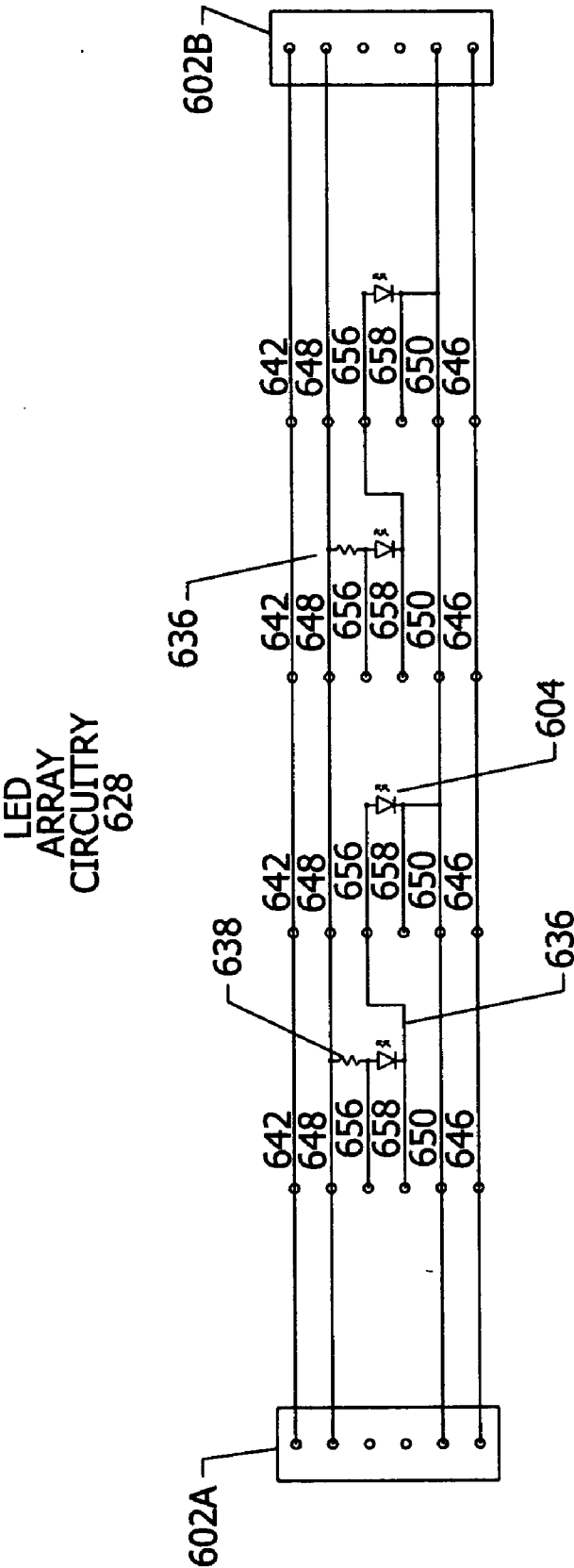


FIG. 53D

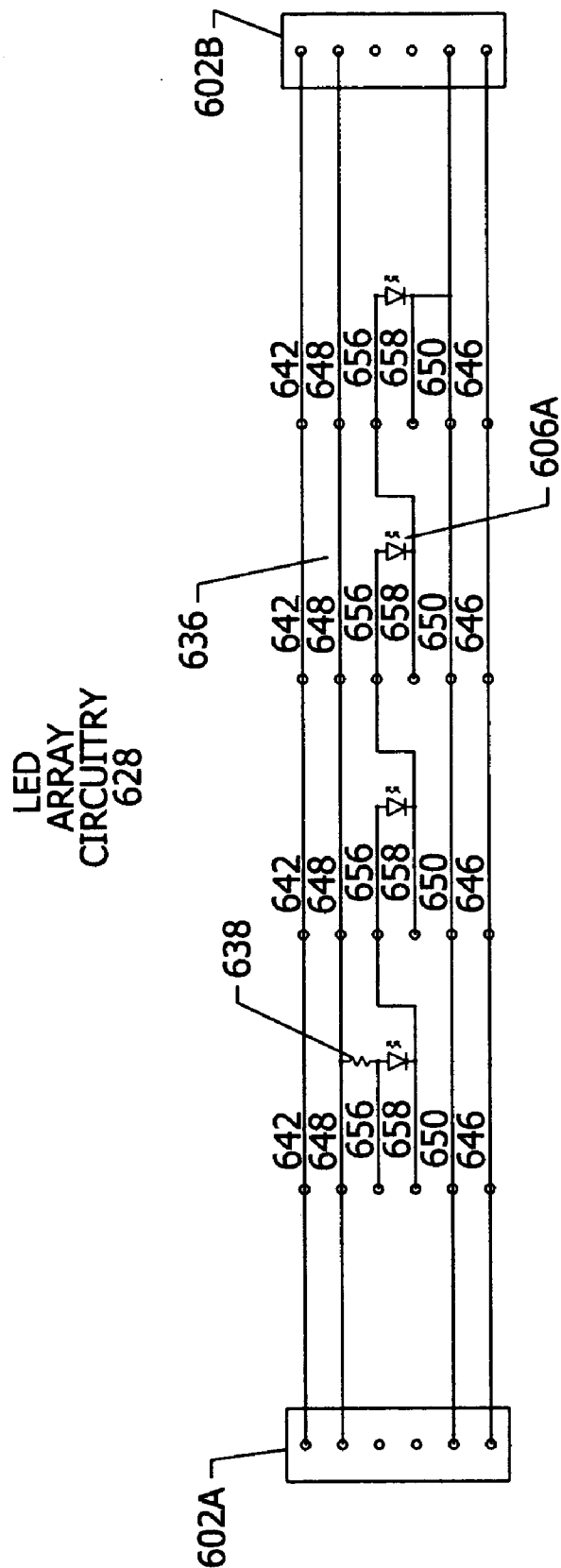


FIG. 53E

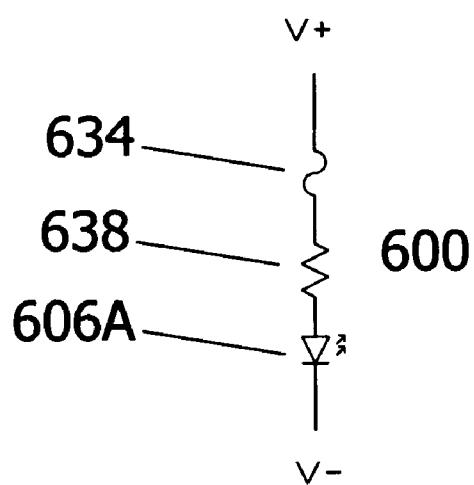


FIG. 53F

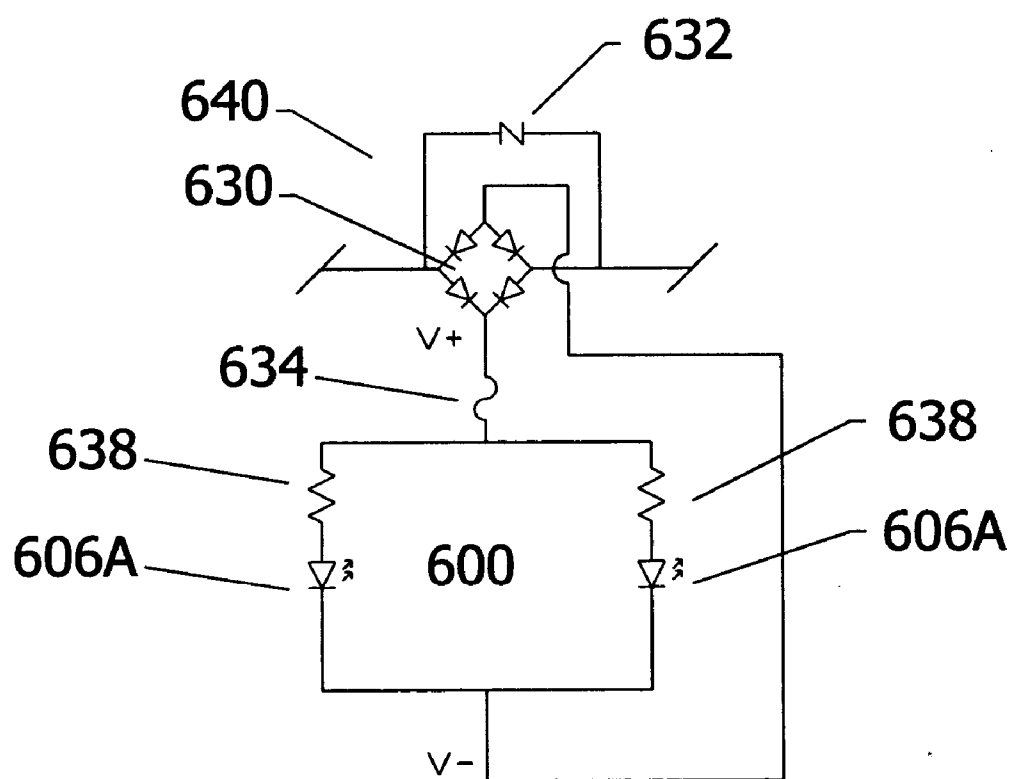


FIG. 53G

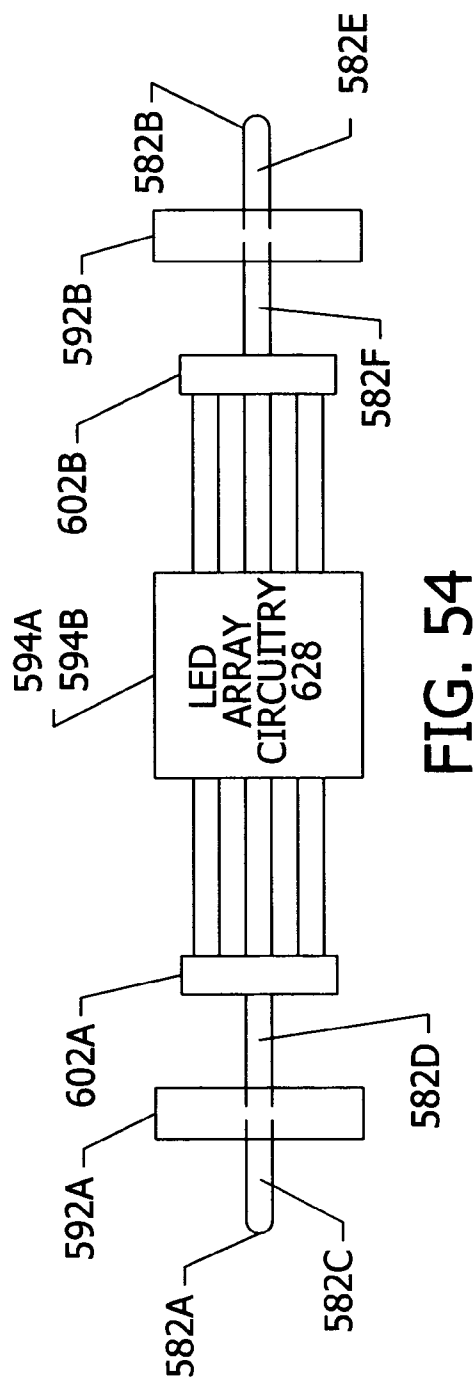
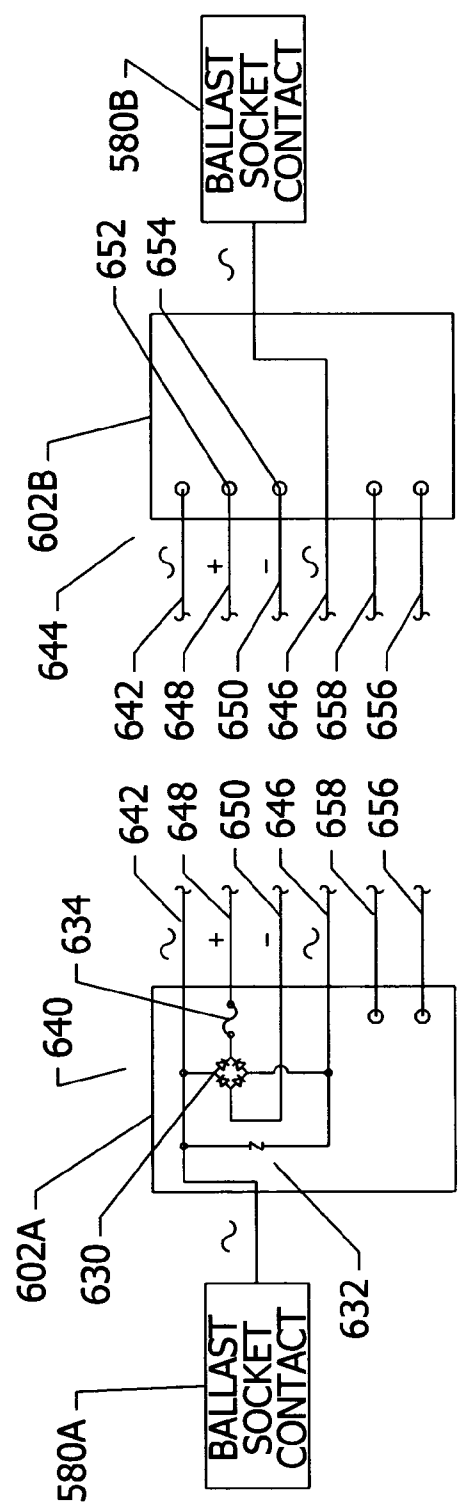


FIG. 56

FIG. 55

+

+

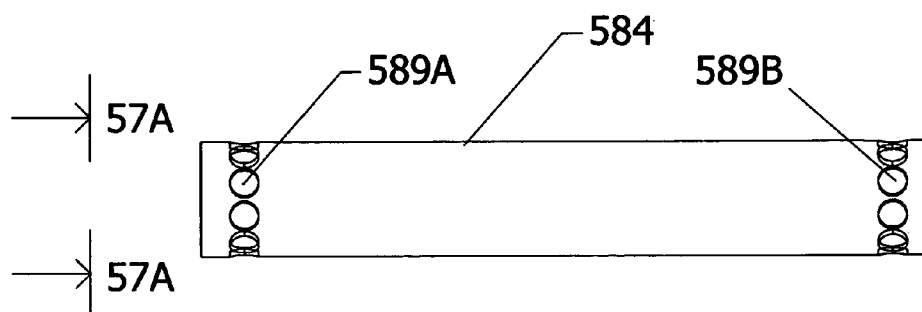


FIG. 57

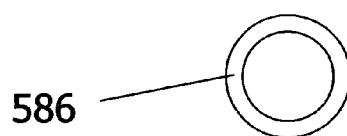


FIG. 57A

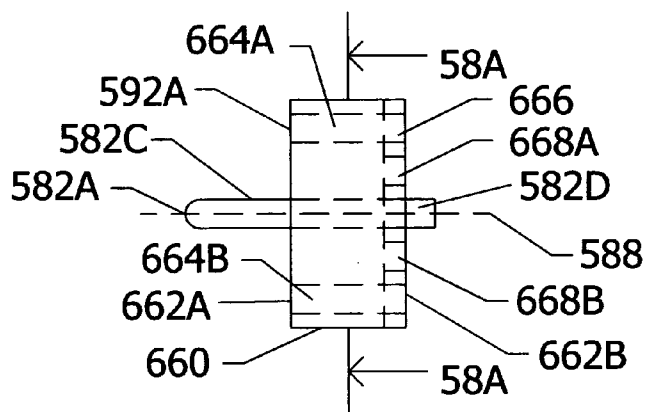


FIG. 58

+

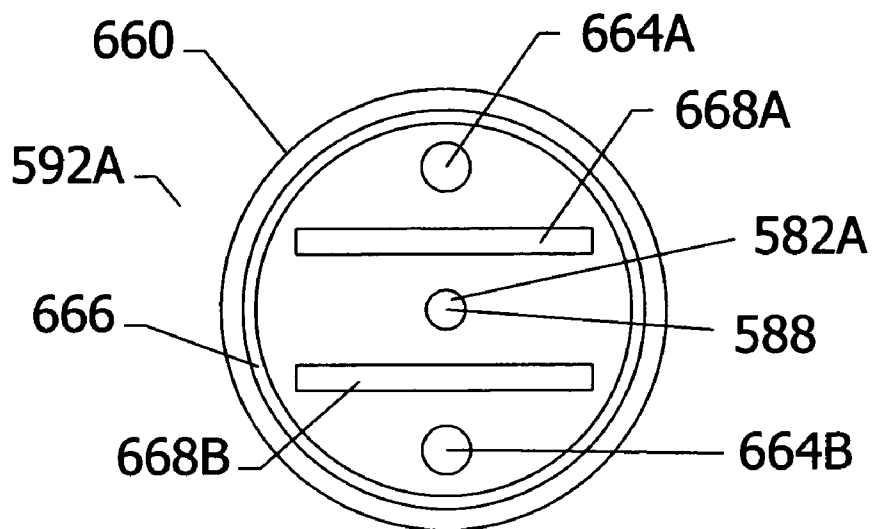


FIG. 58A

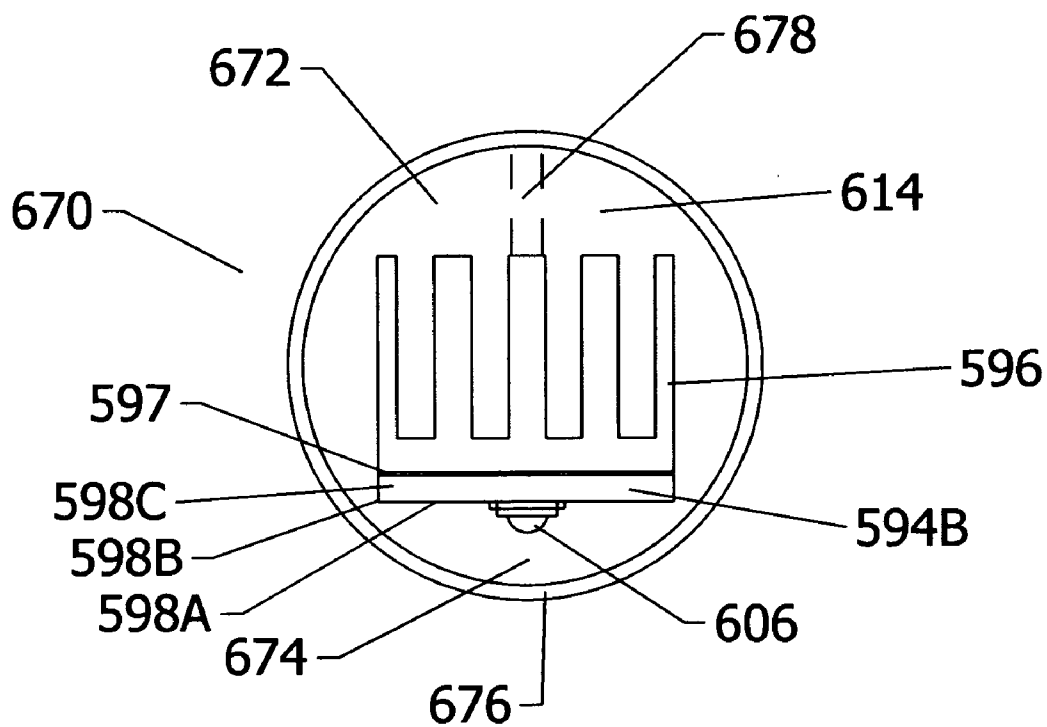


FIG. 59

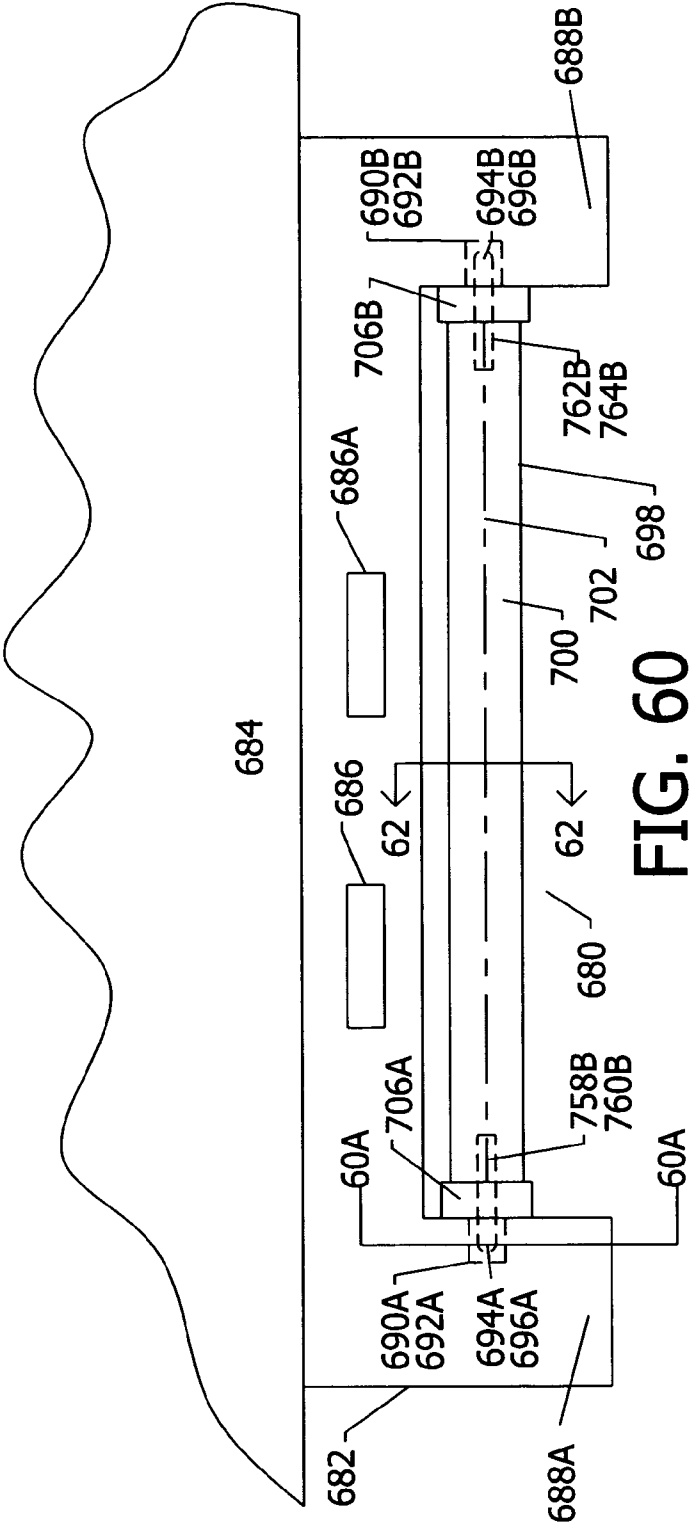


FIG. 60

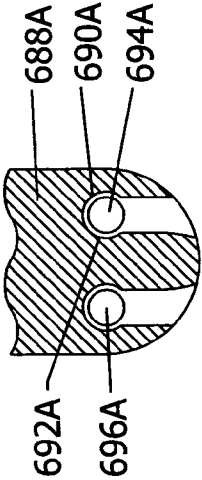
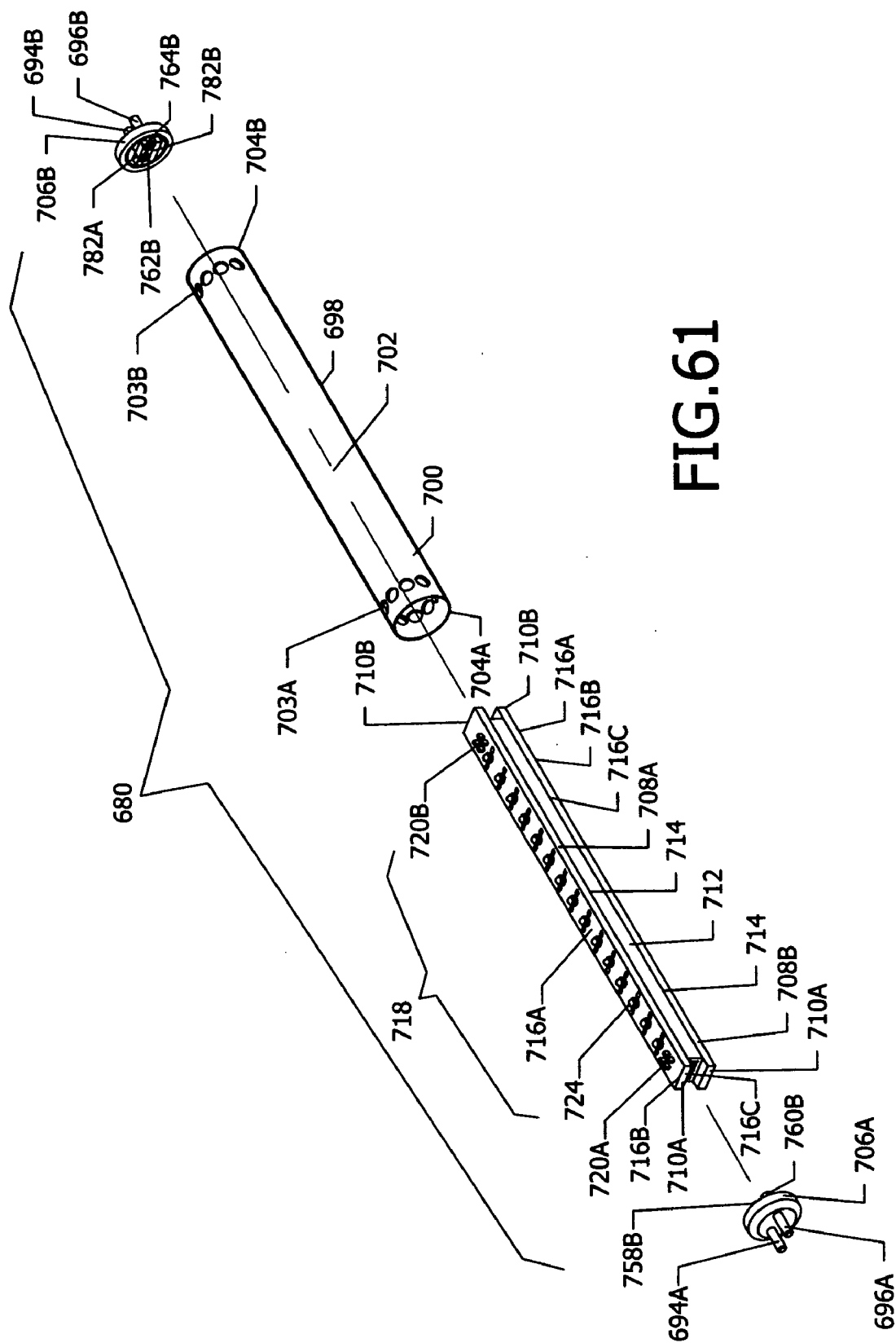


FIG. 60A



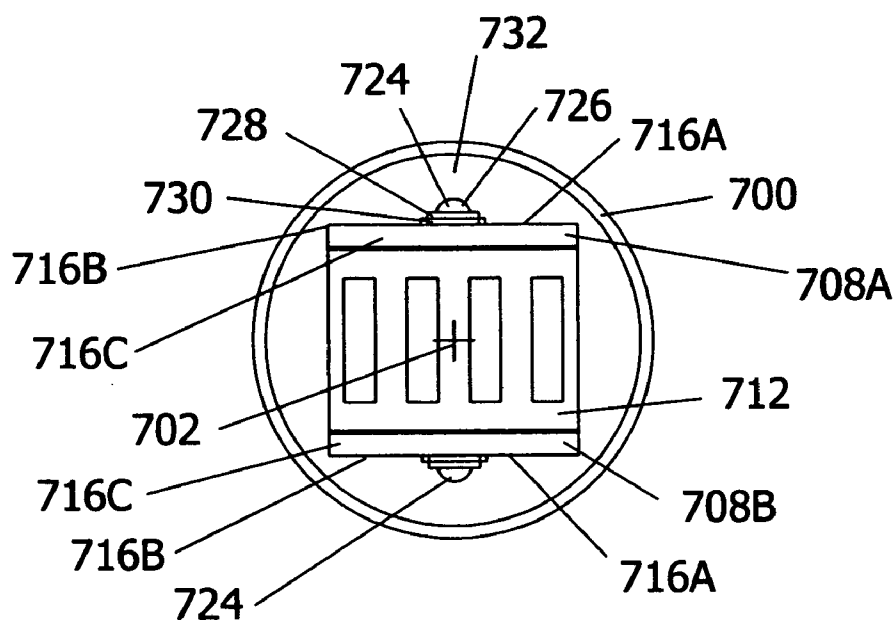


FIG. 62

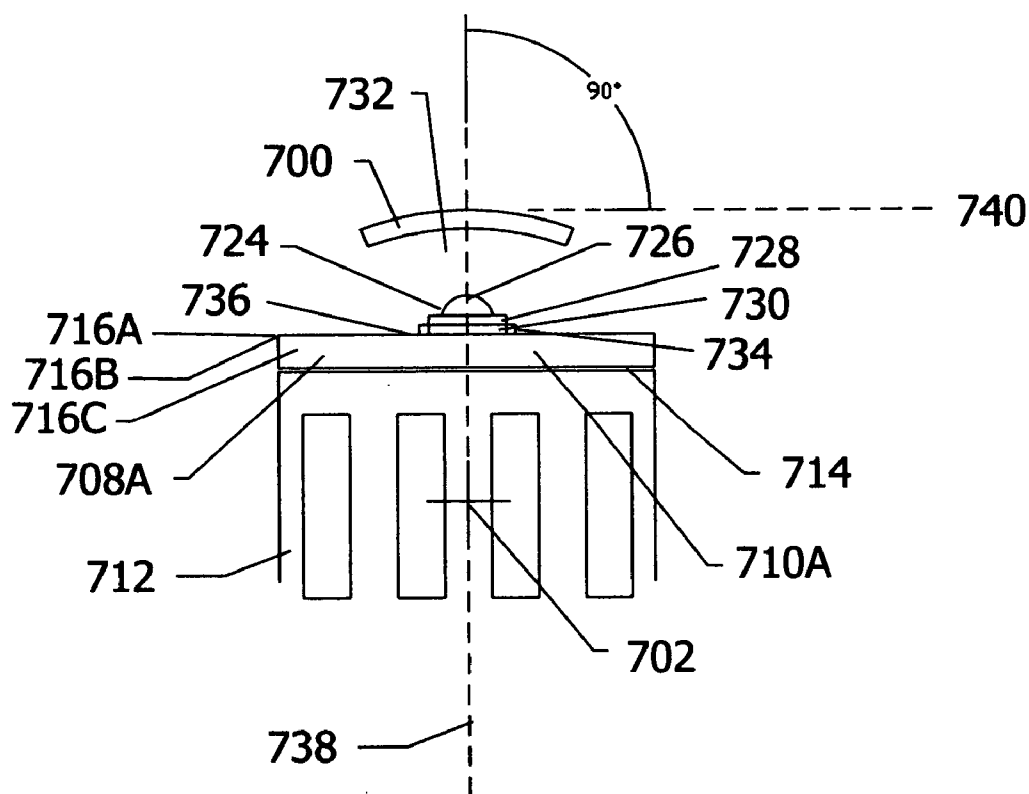


FIG. 62A

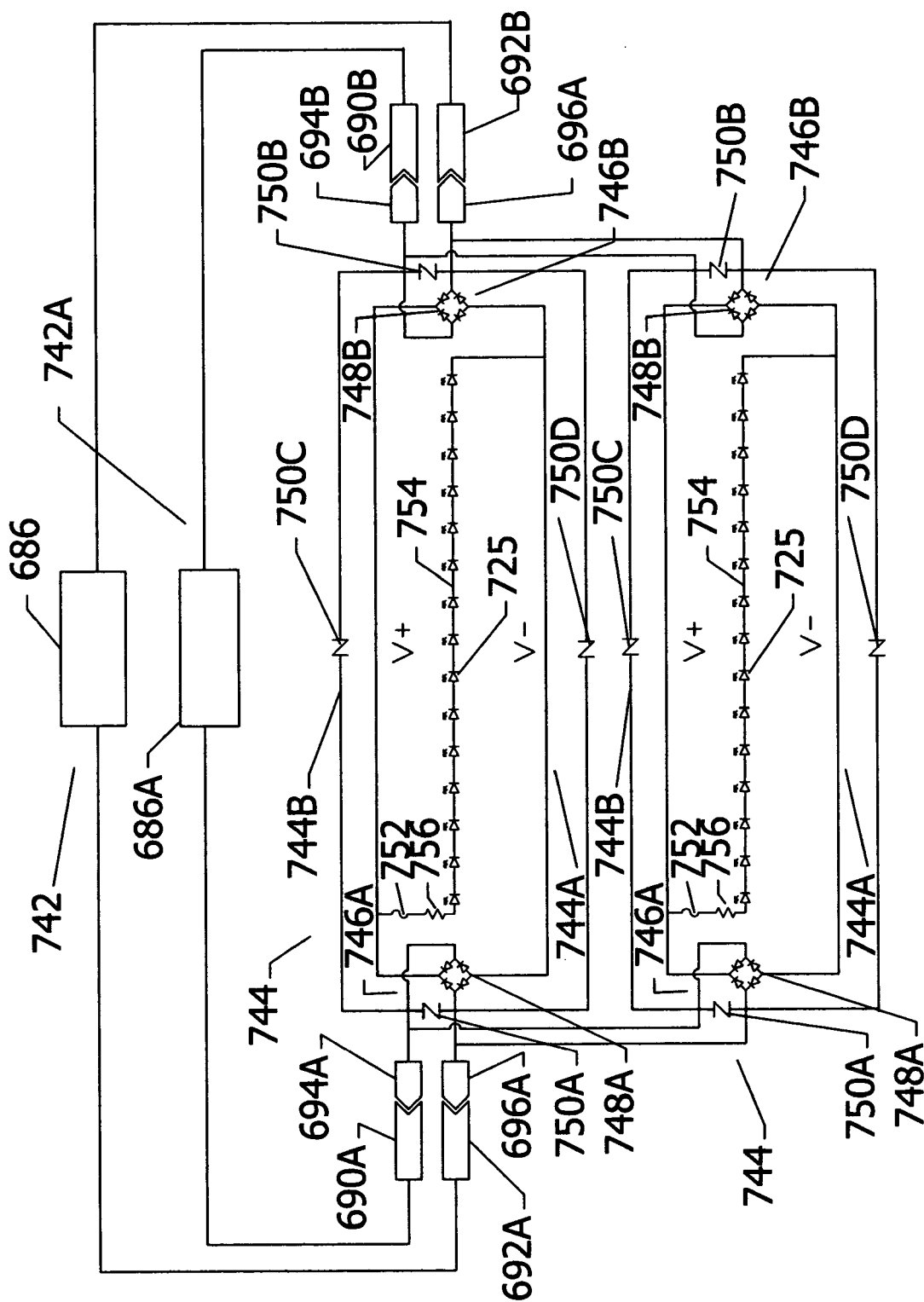


FIG. 63

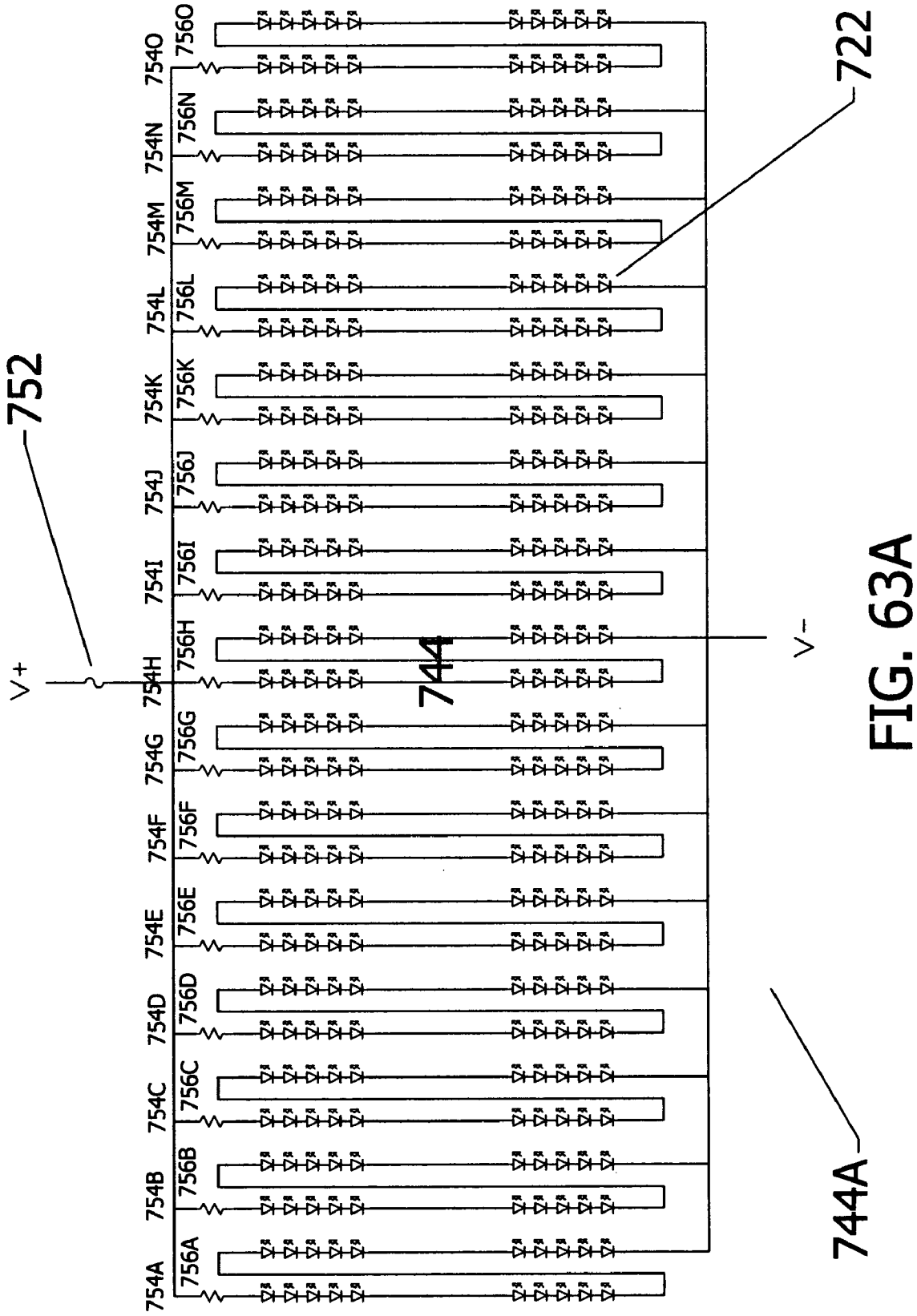


FIG. 63A

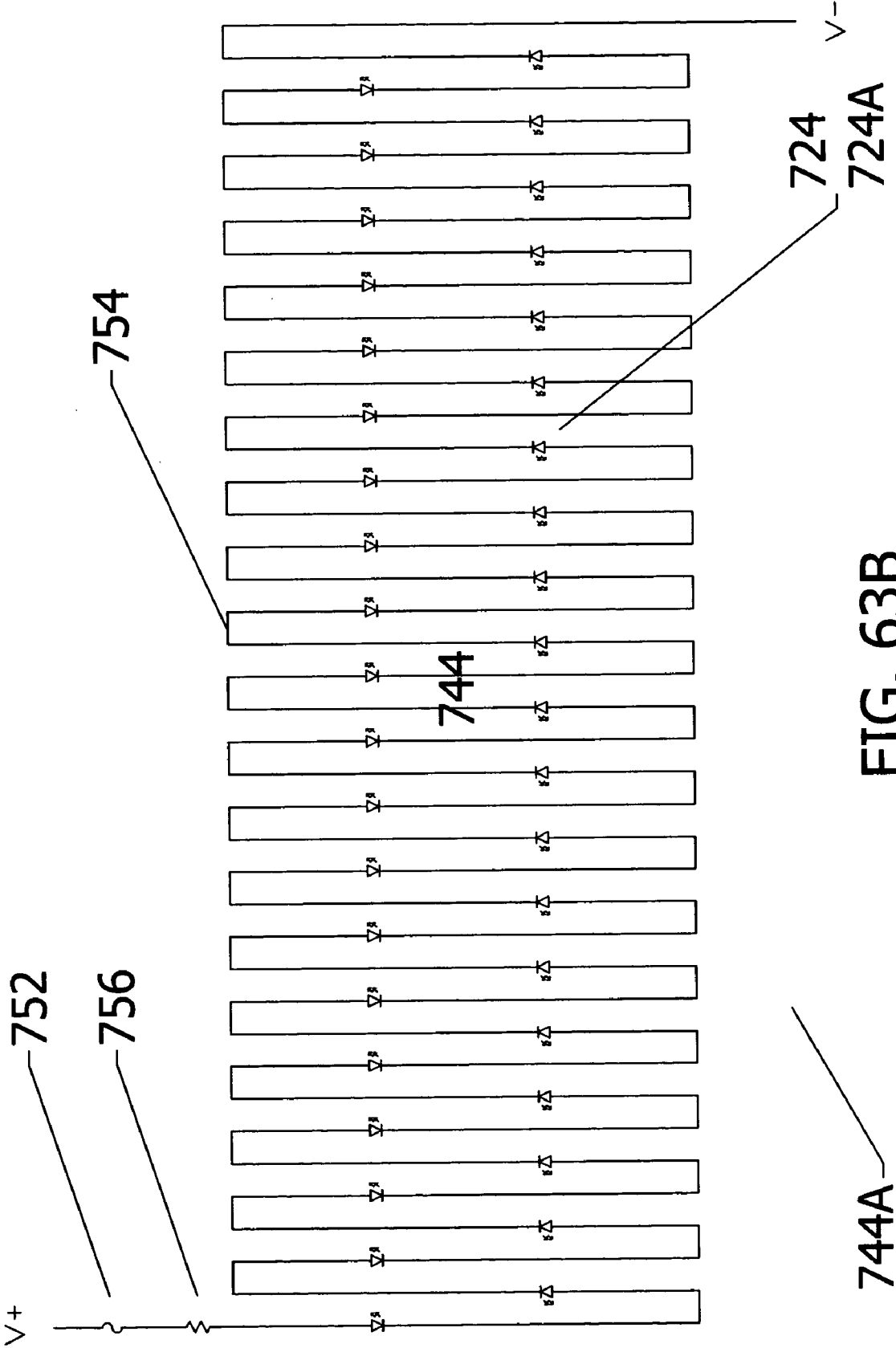


FIG. 63B

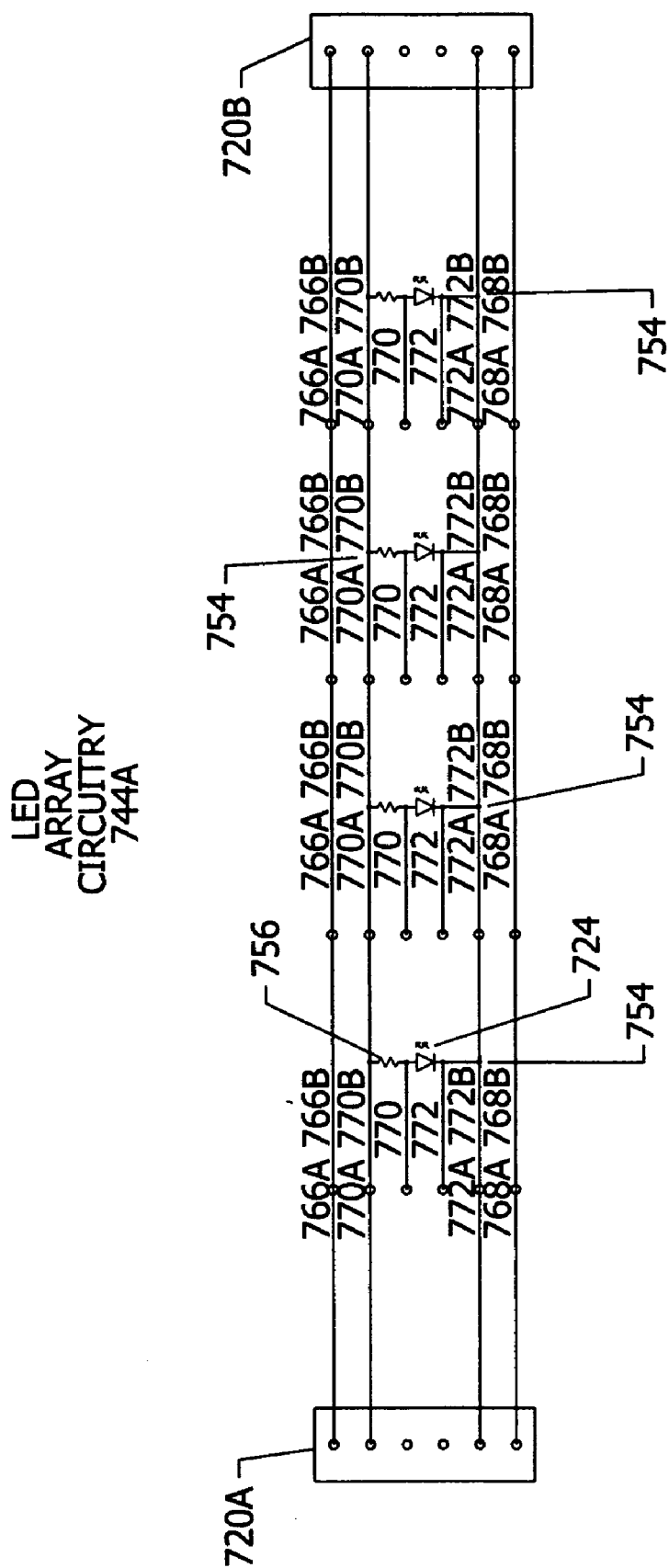


FIG. 63C

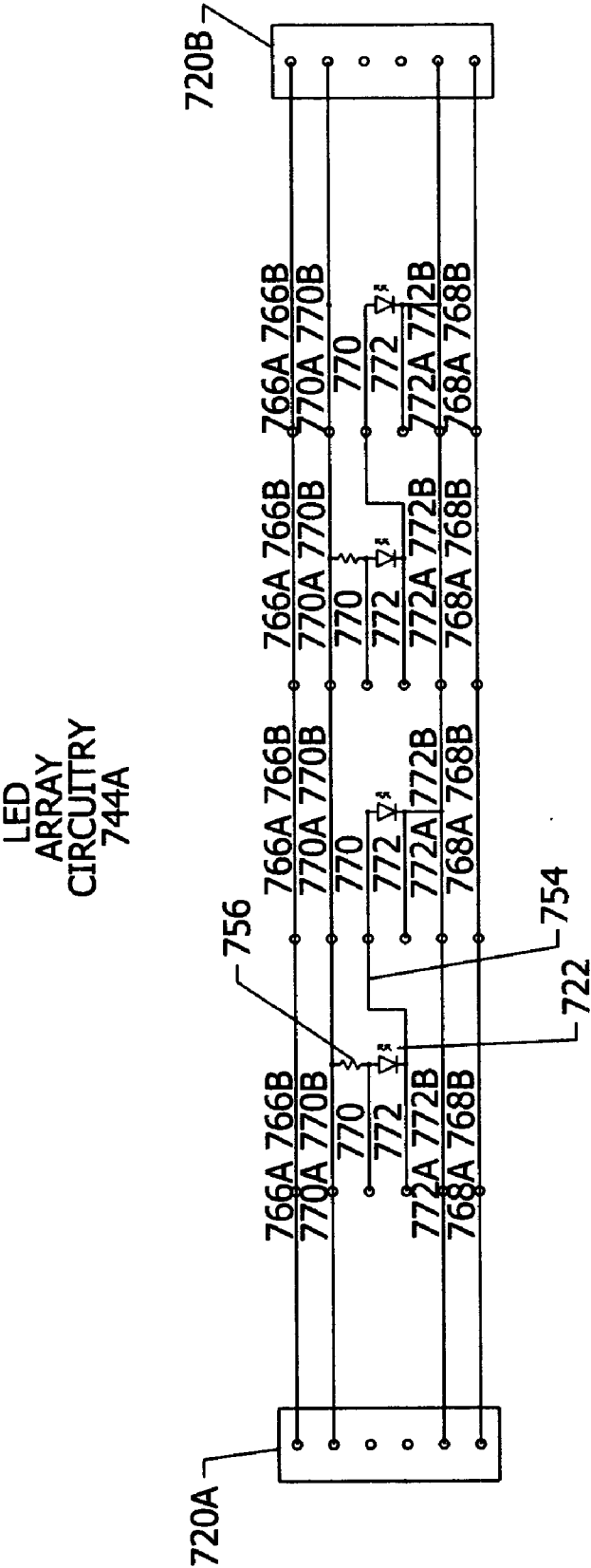


FIG. 63D

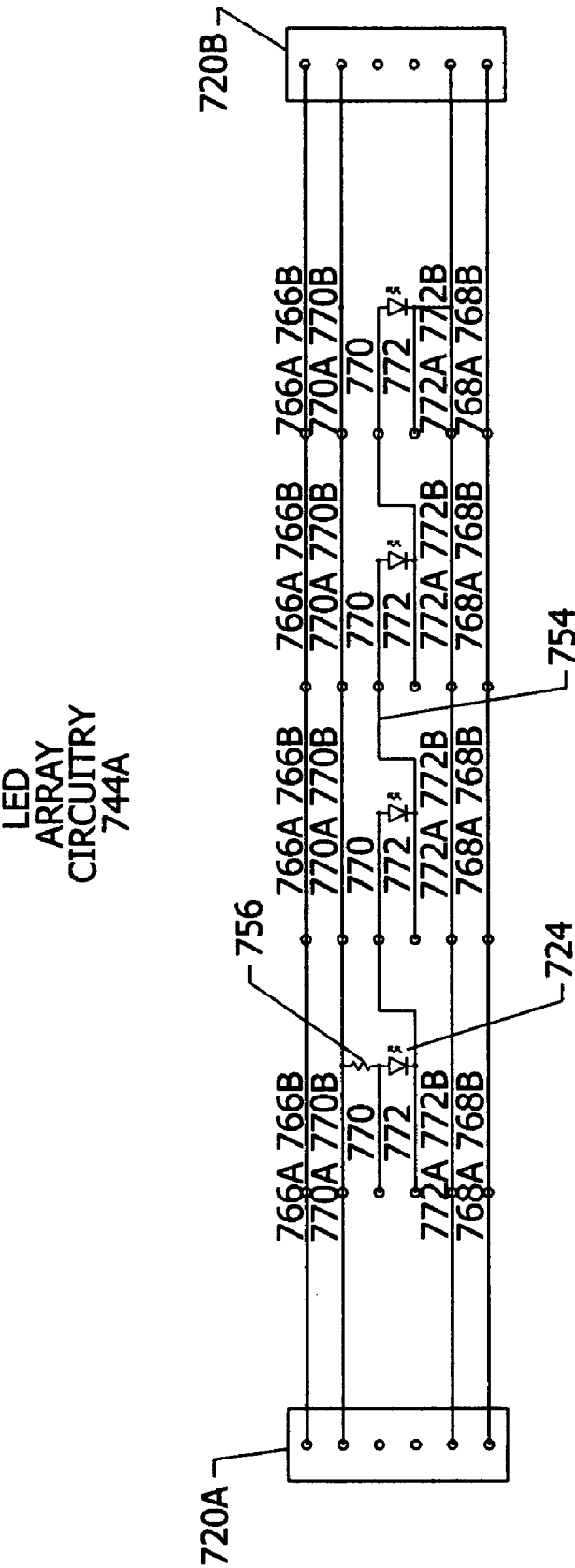


FIG. 63E

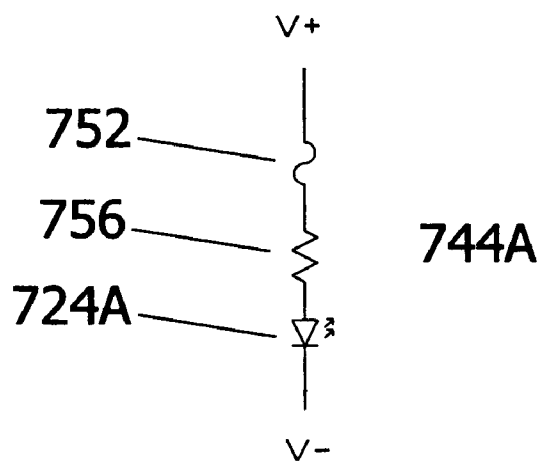


FIG. 63F

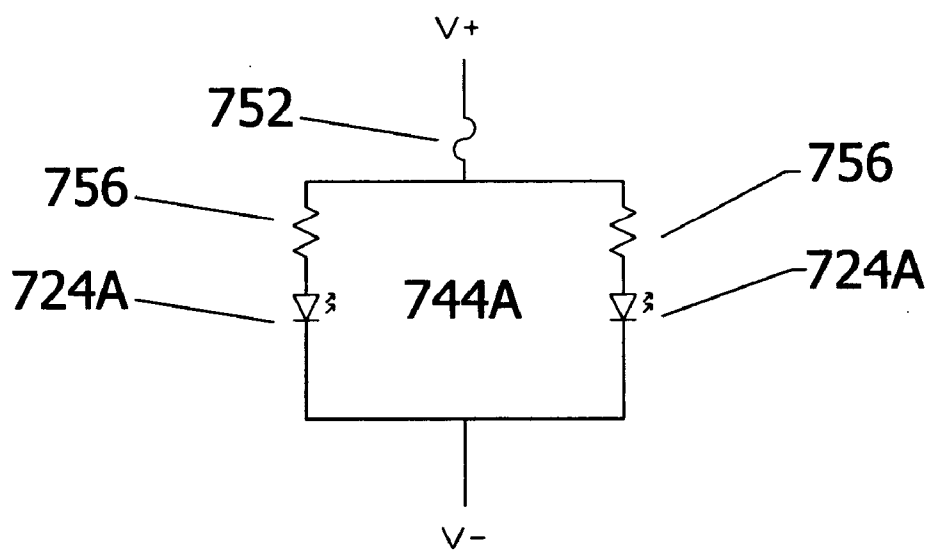
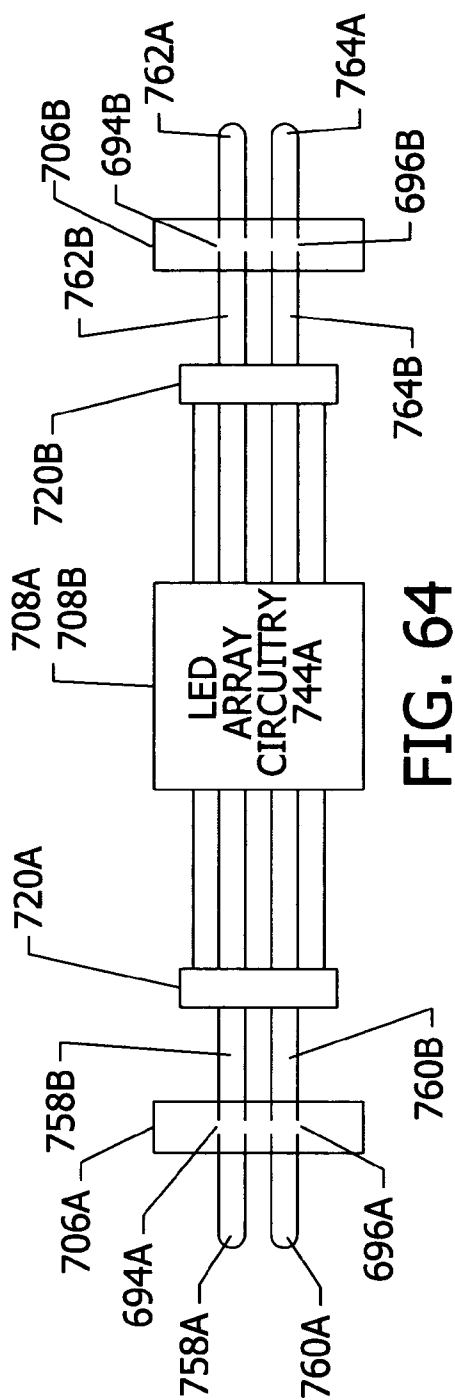
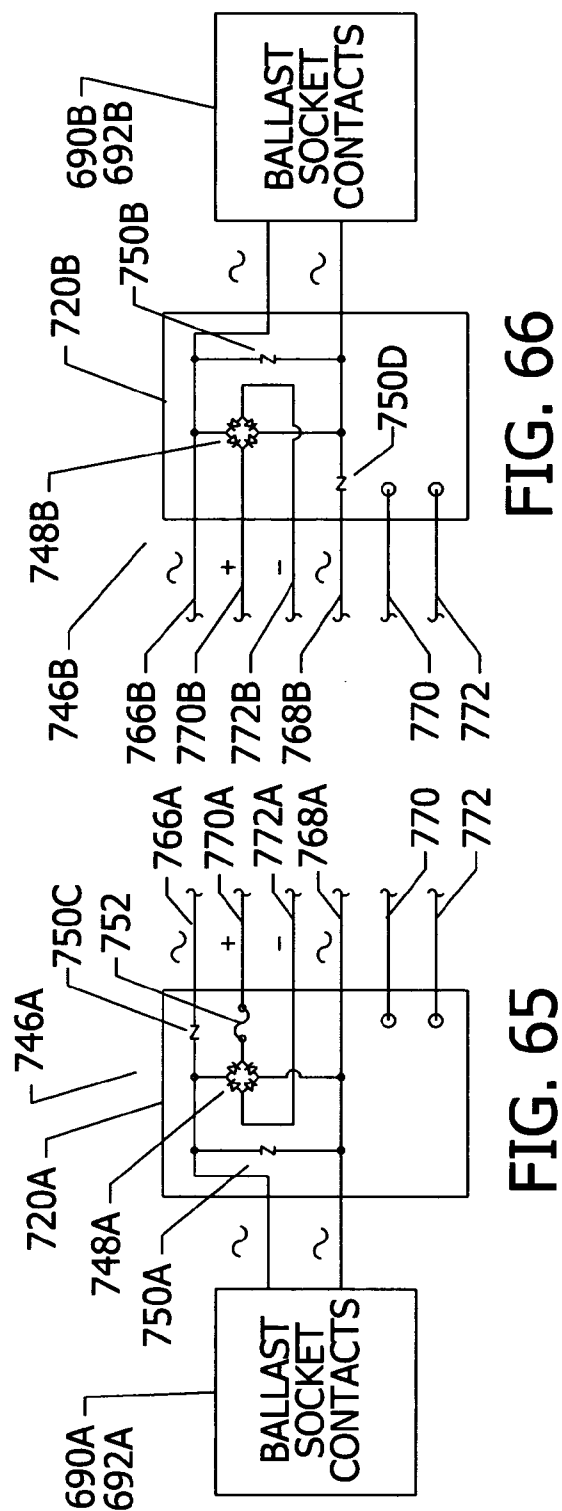


FIG. 63G



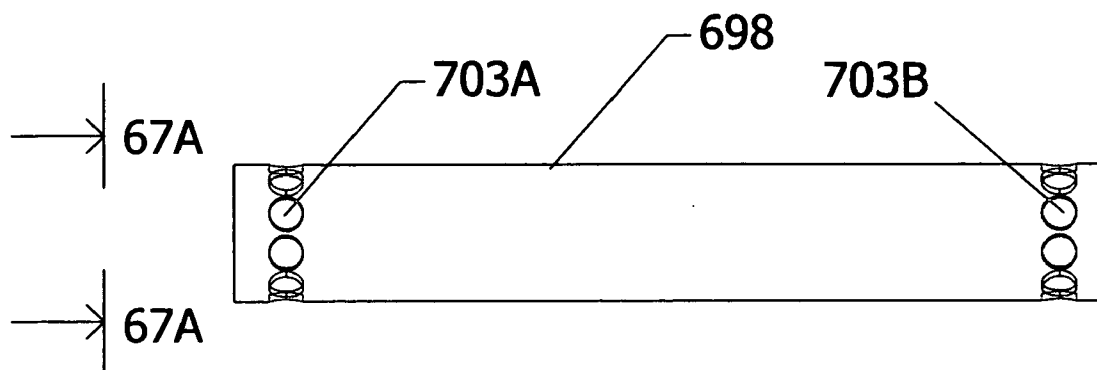


FIG. 67

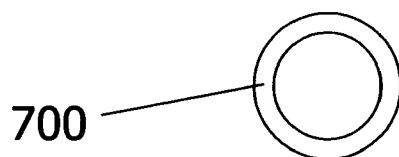


FIG. 67A

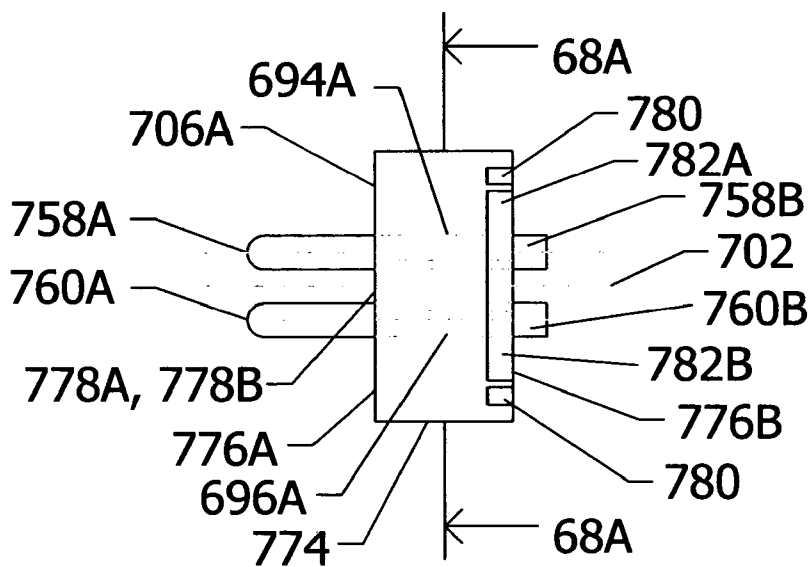


FIG. 68

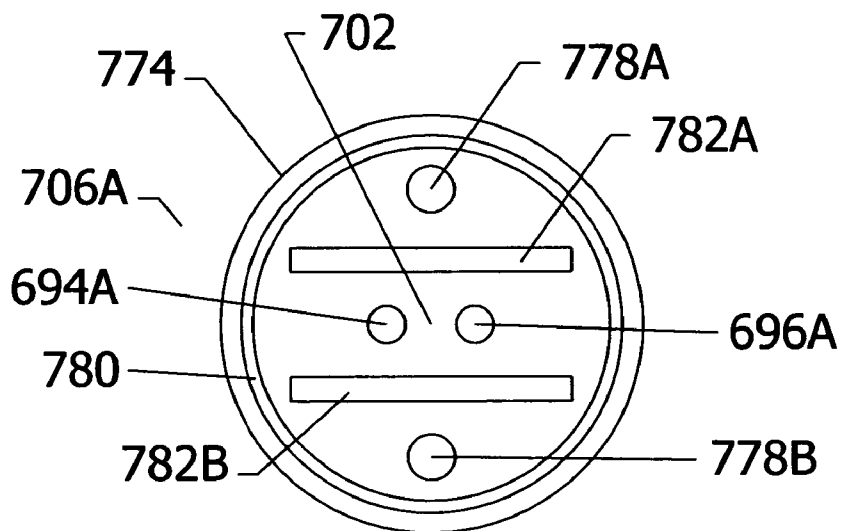


FIG. 68A

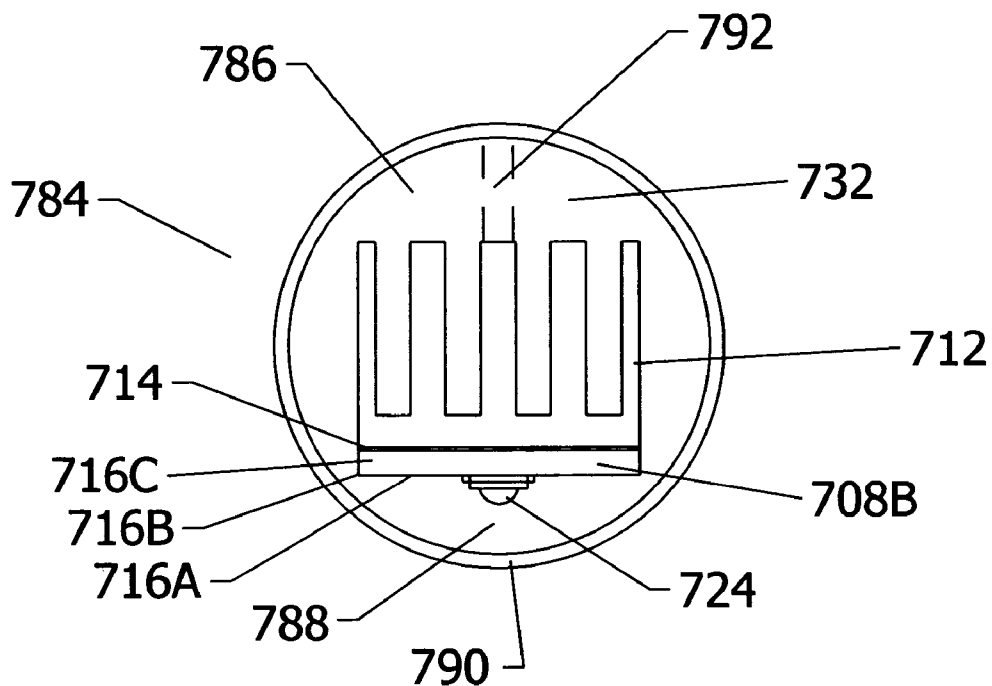


FIG. 69

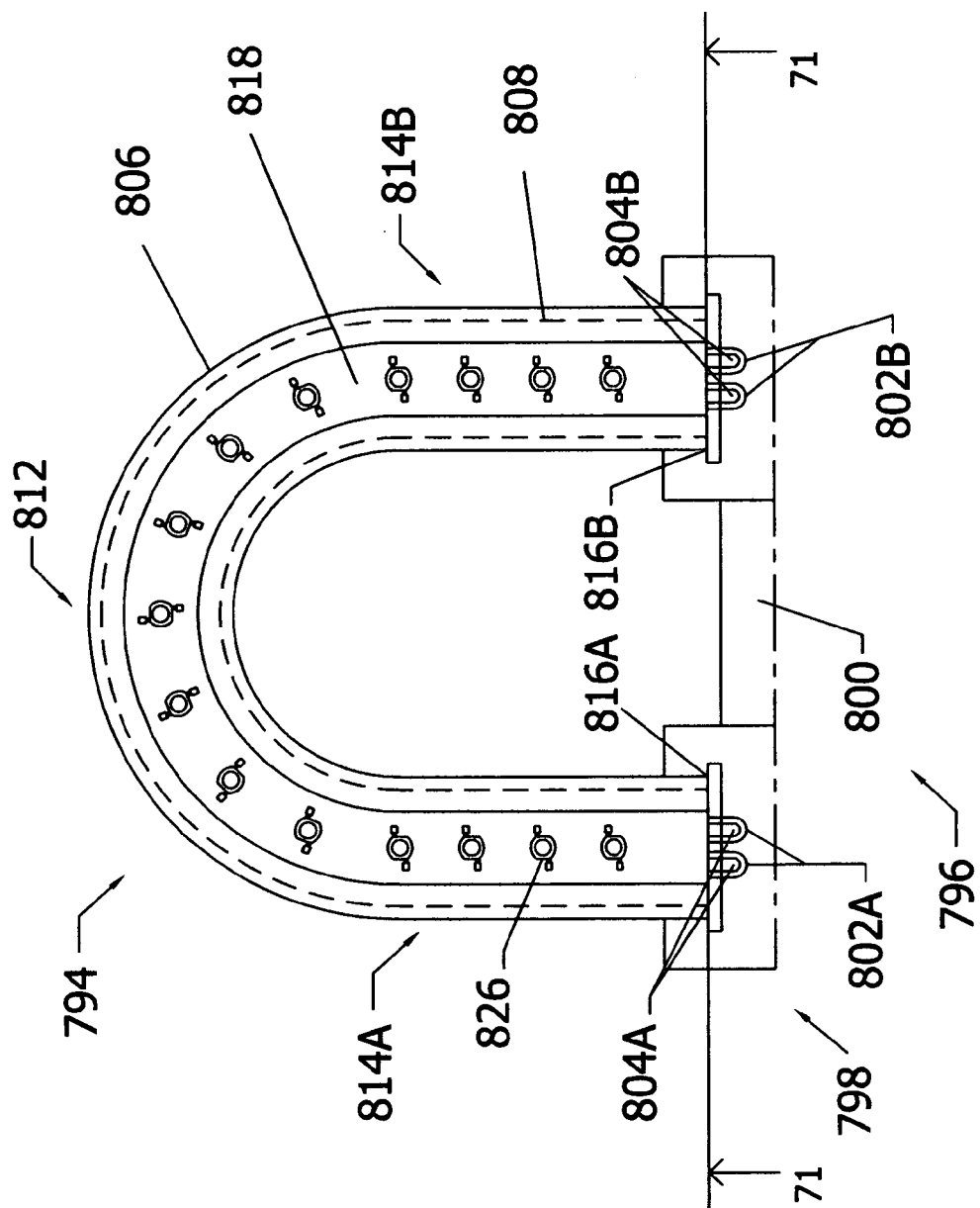


FIG. 70

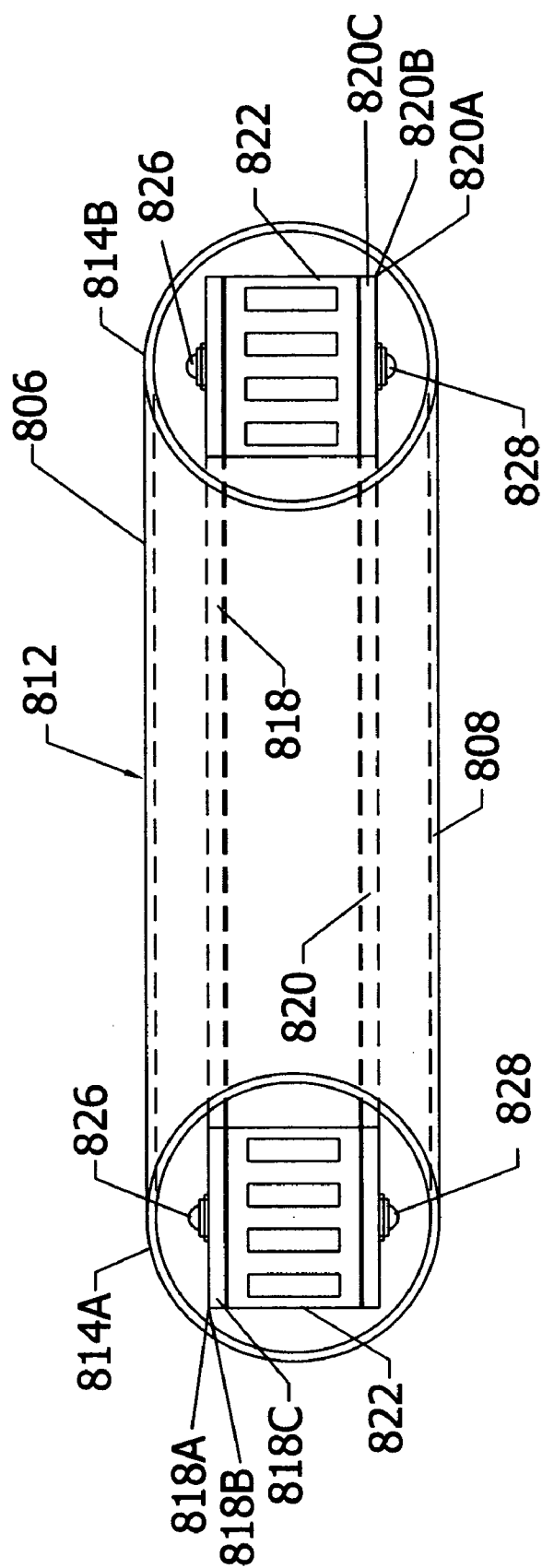


FIG. 71

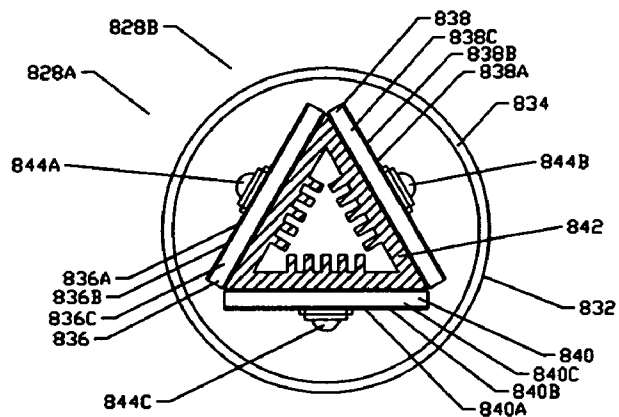


FIG. 72

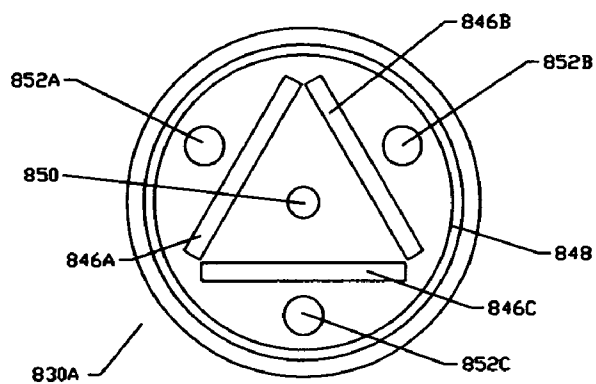


FIG. 72A

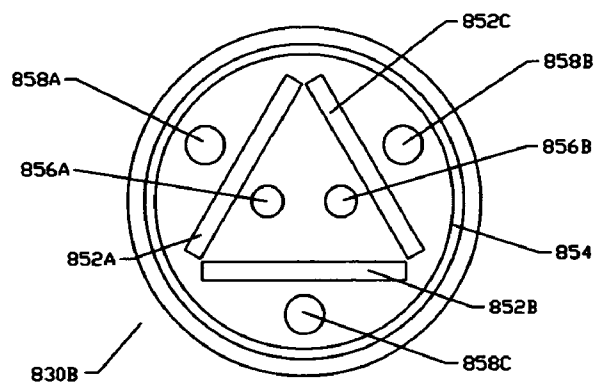
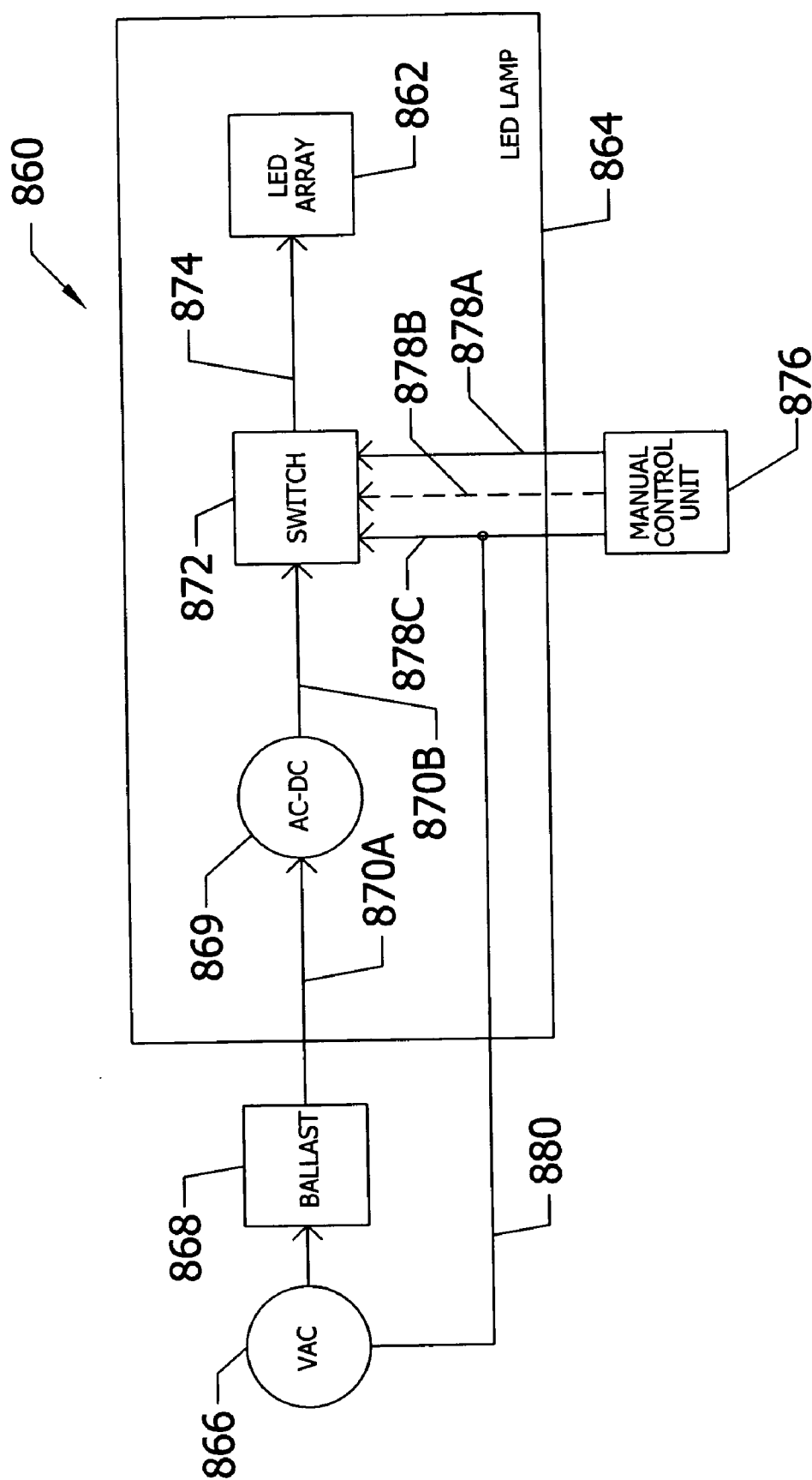
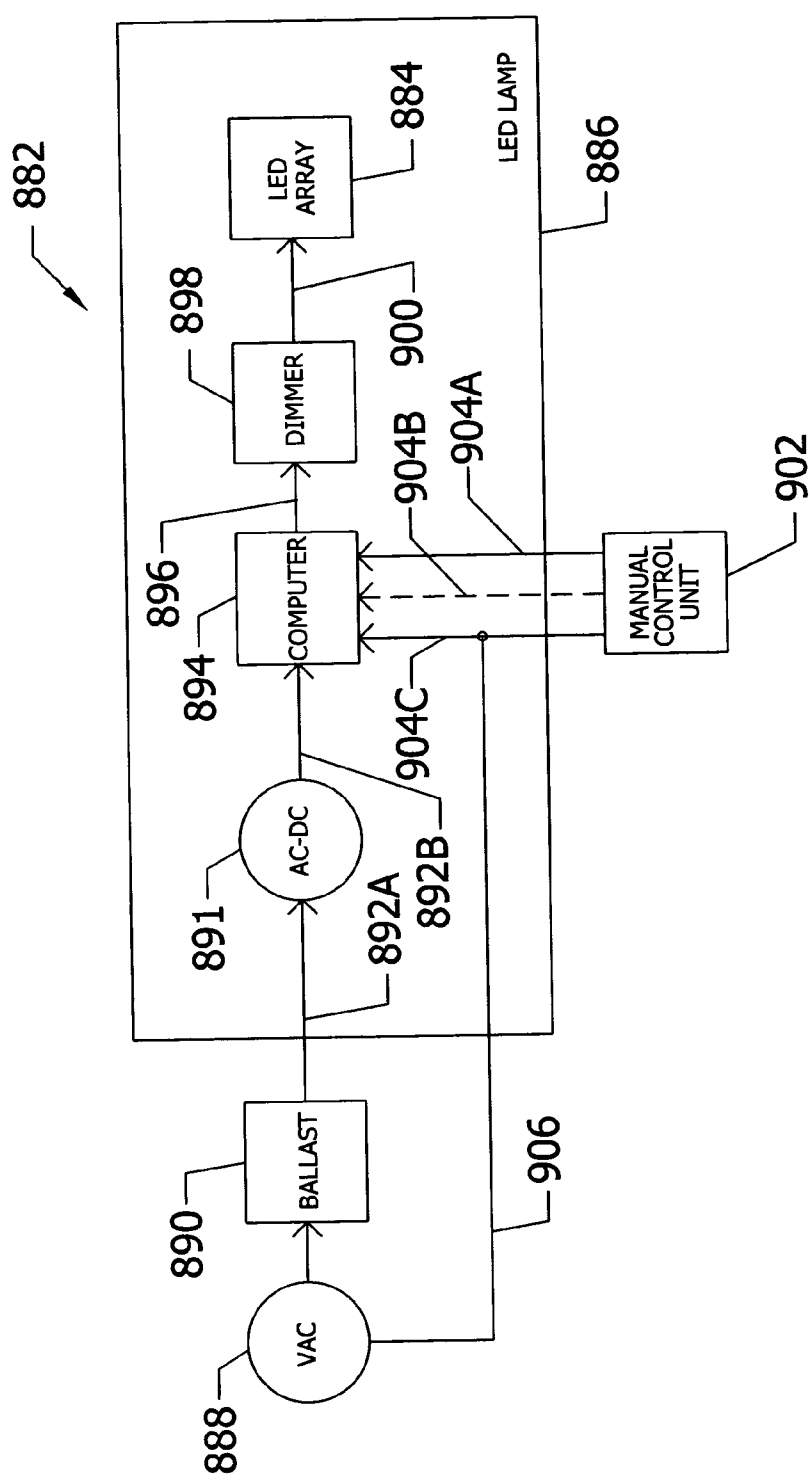


FIG. 72B





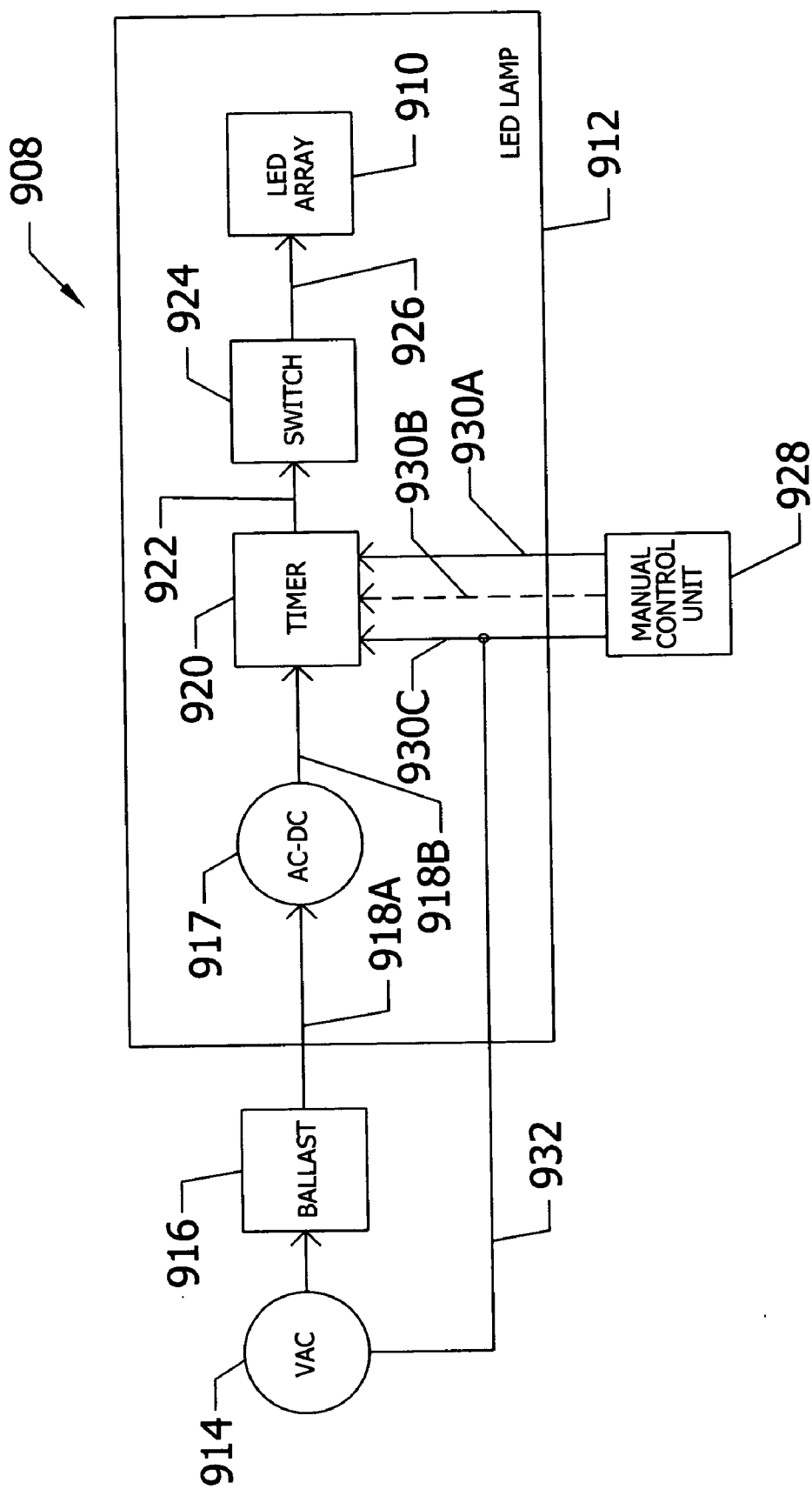


FIG. 74

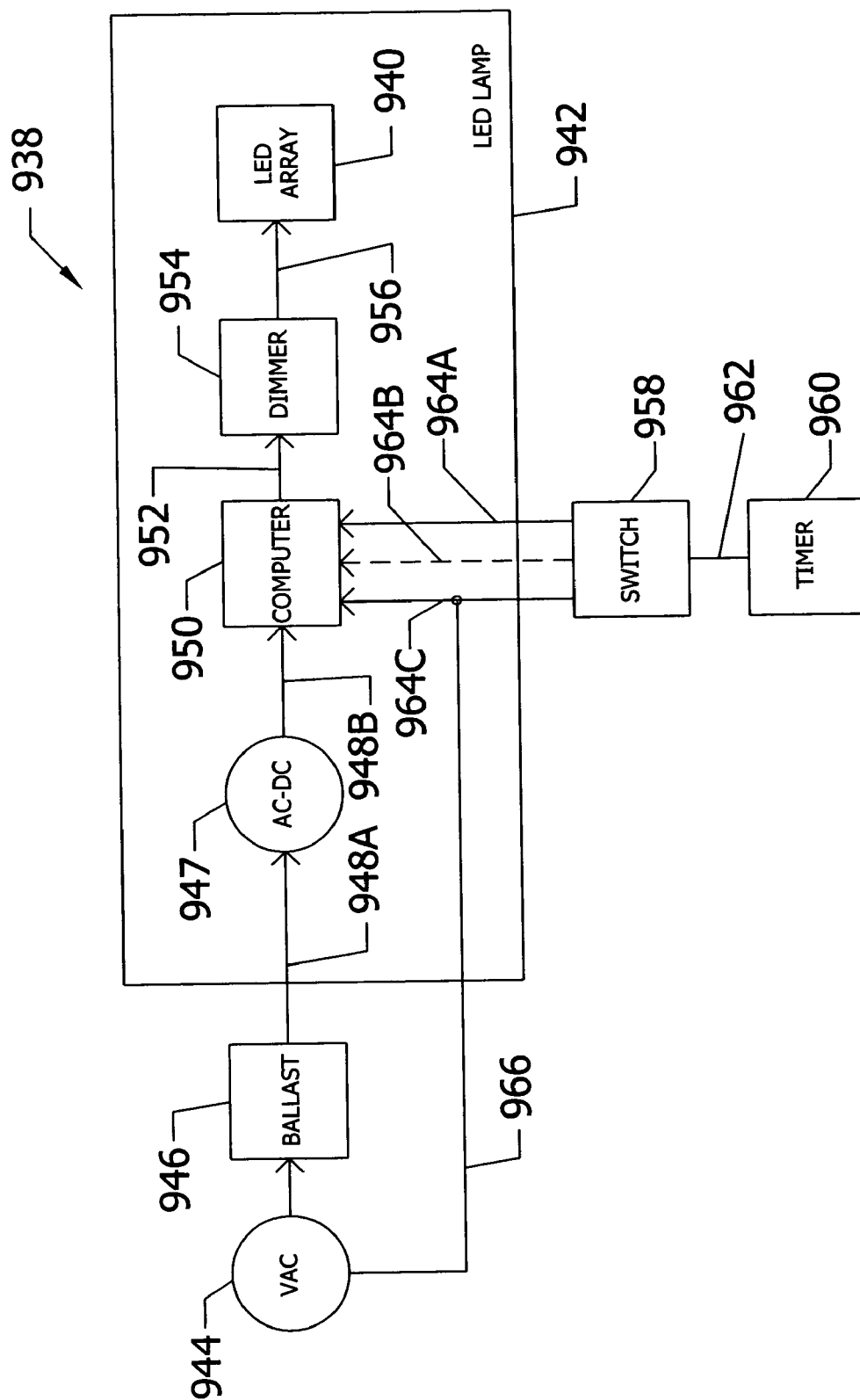


FIG. 74A

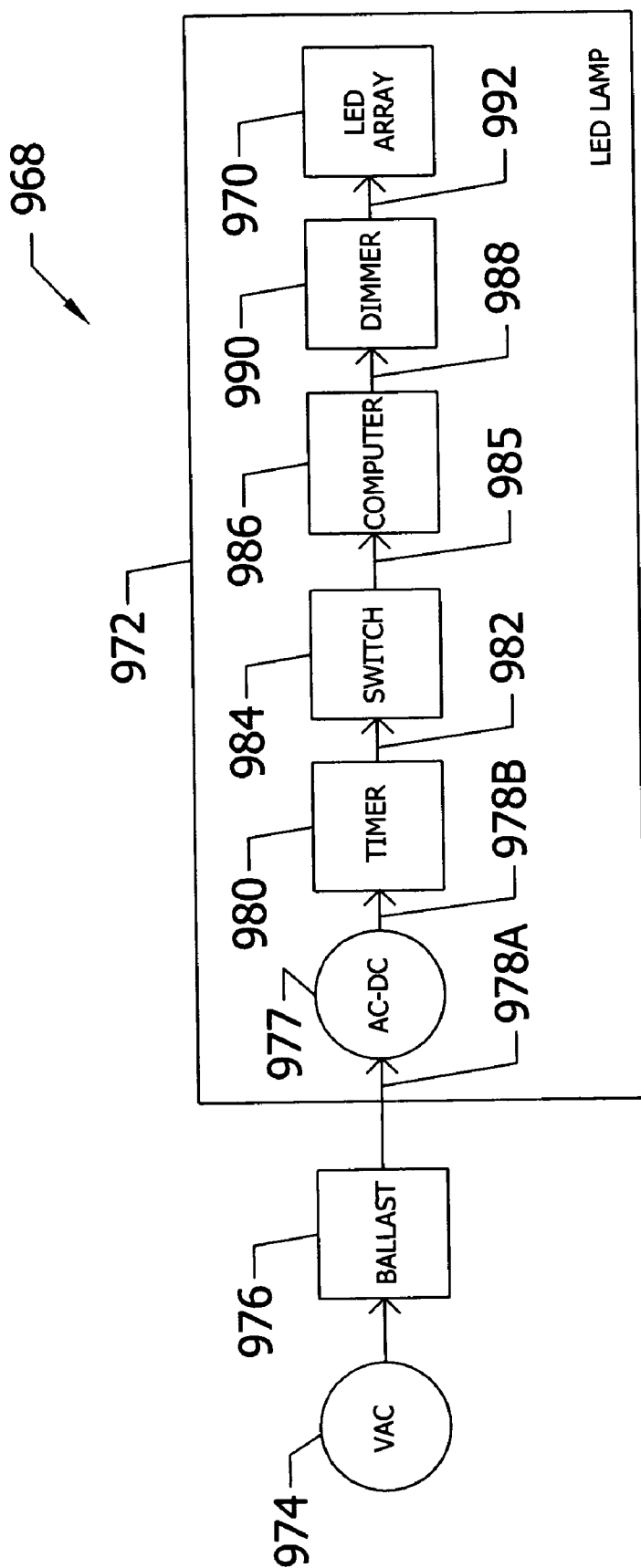


FIG. 74B

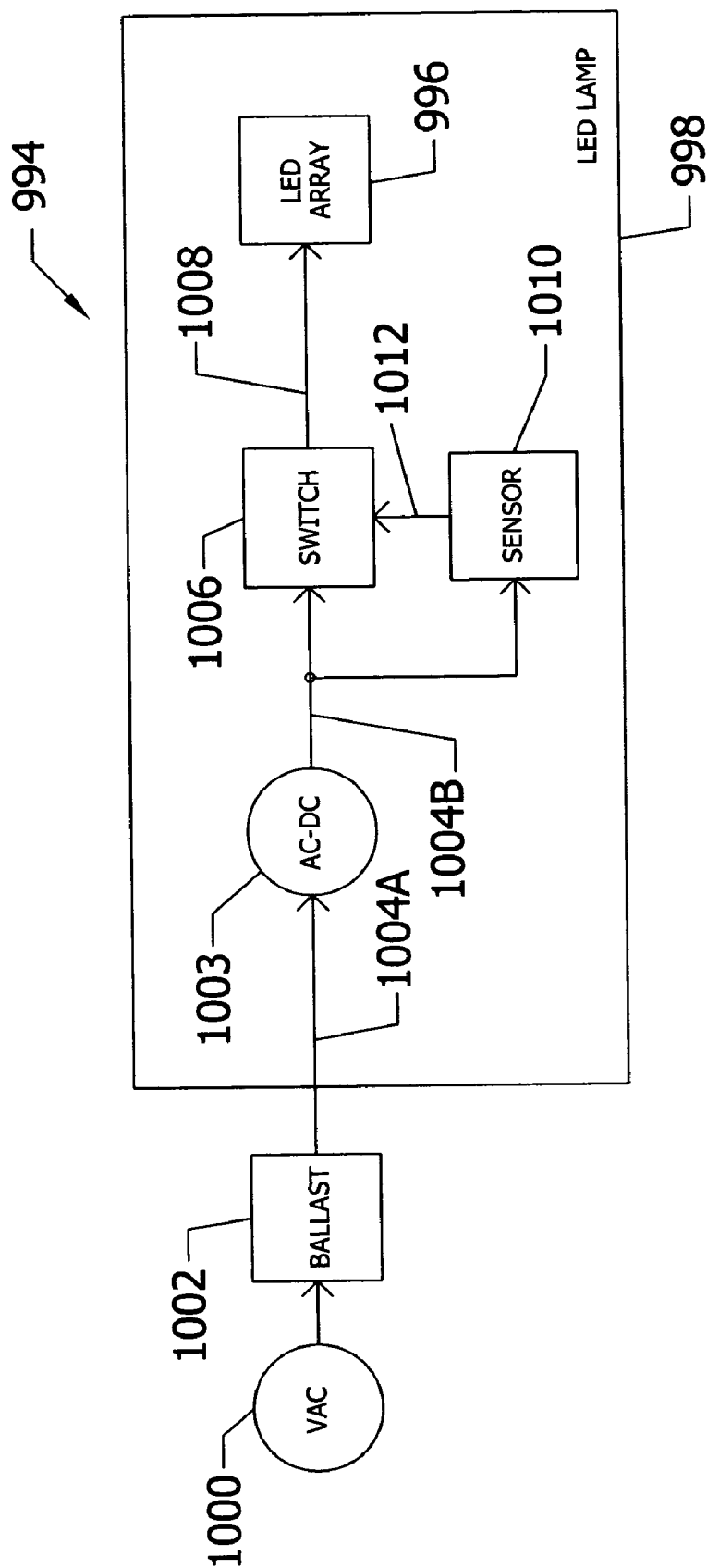


FIG. 75

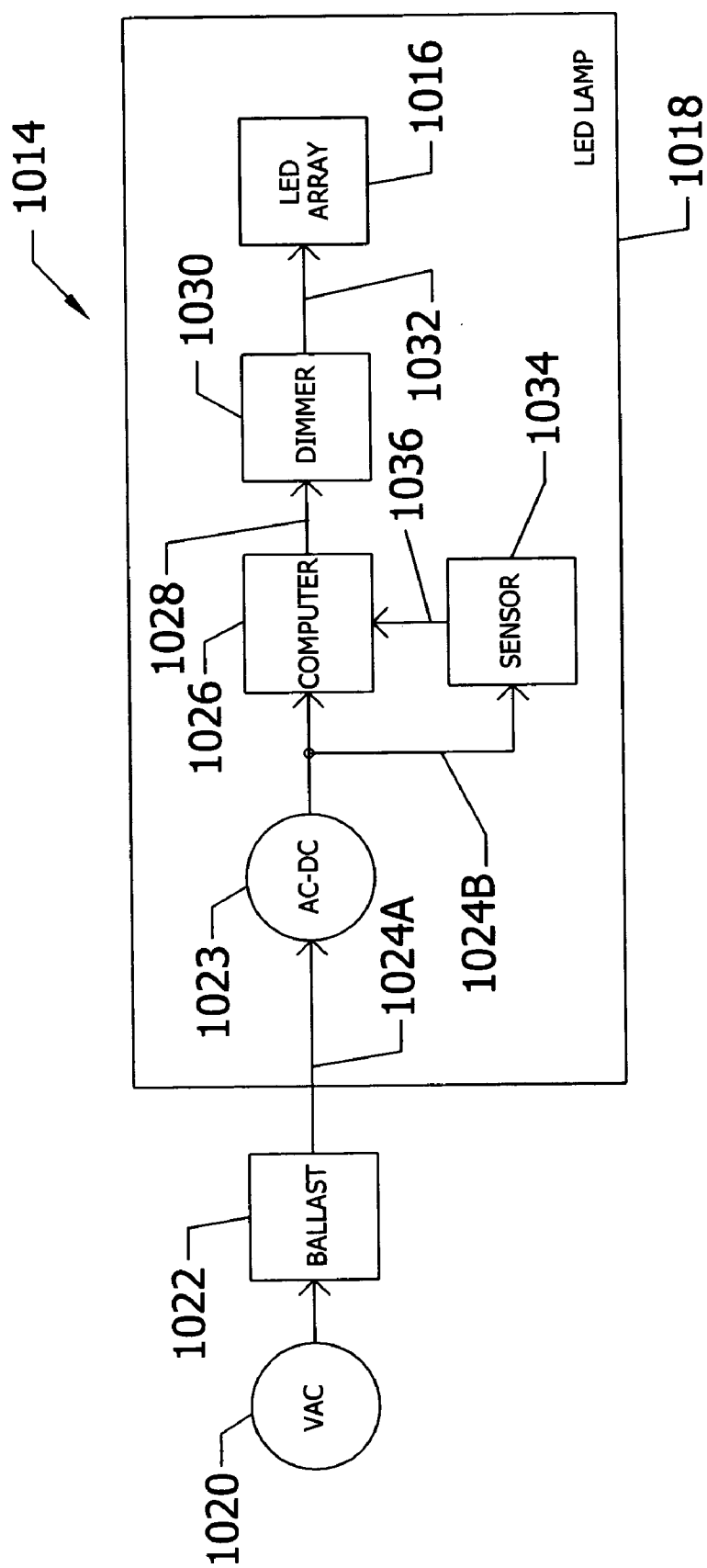


FIG. 75A

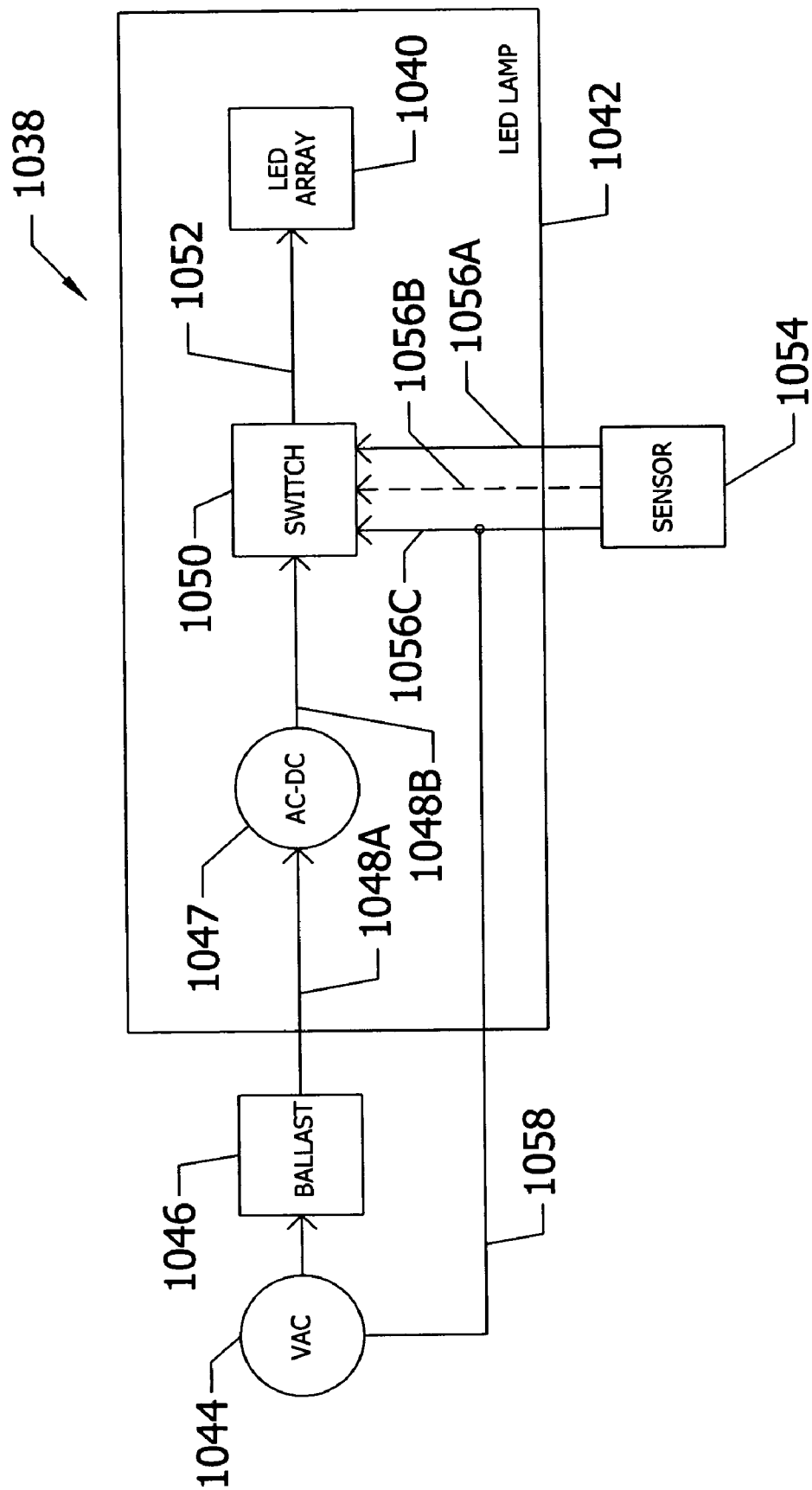


FIG. 75B

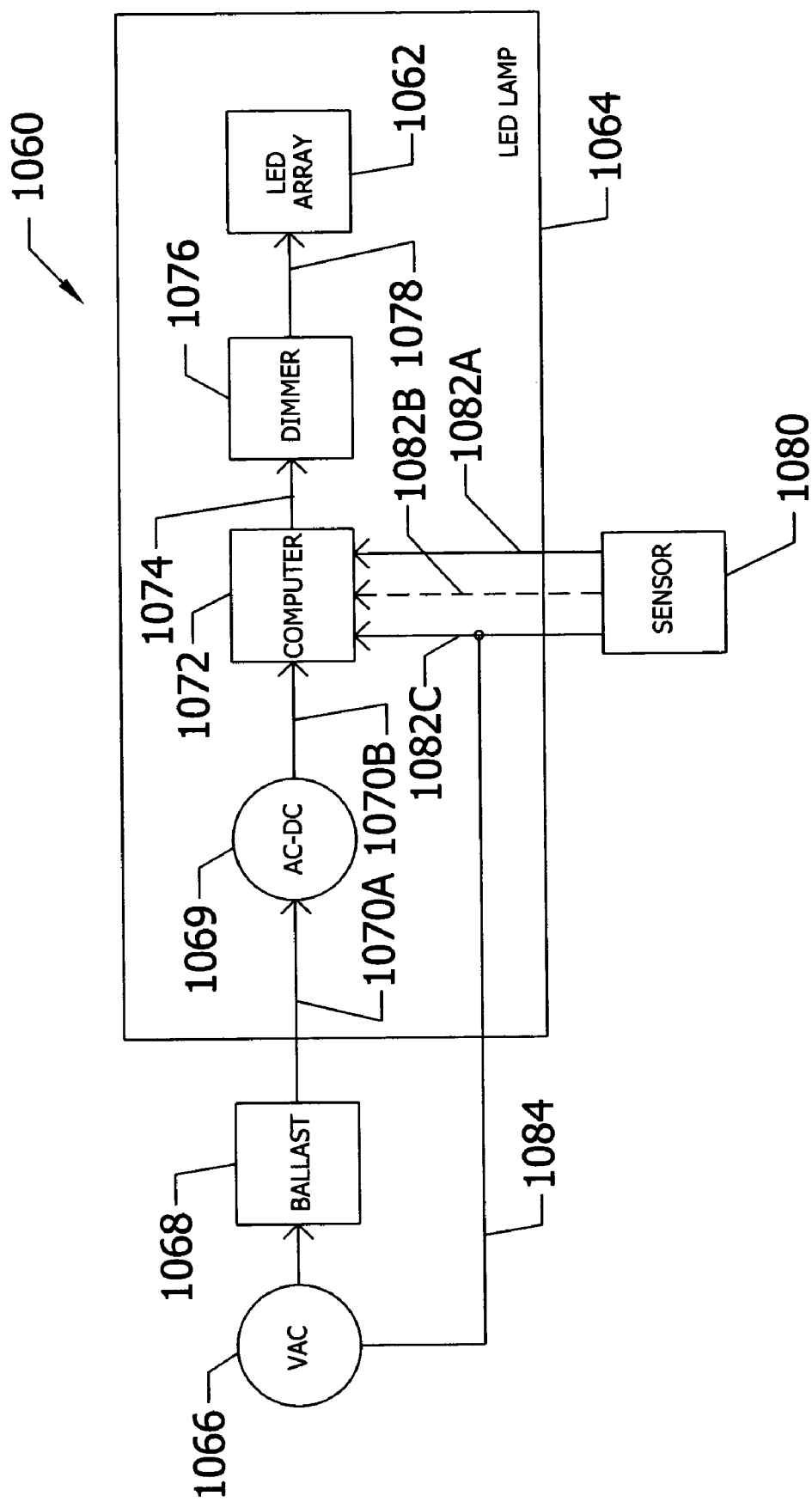


FIG. 75C

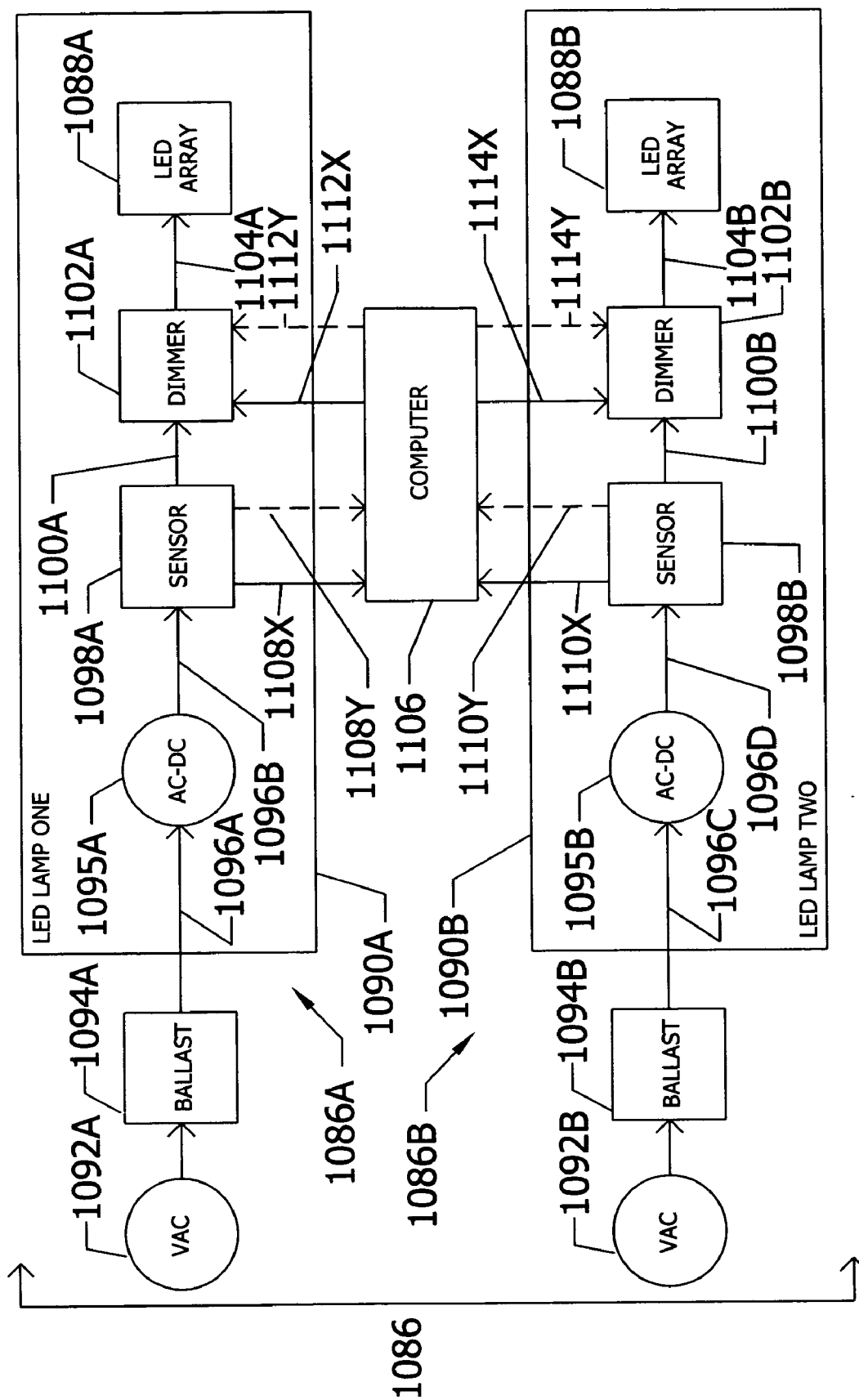


FIG. 76

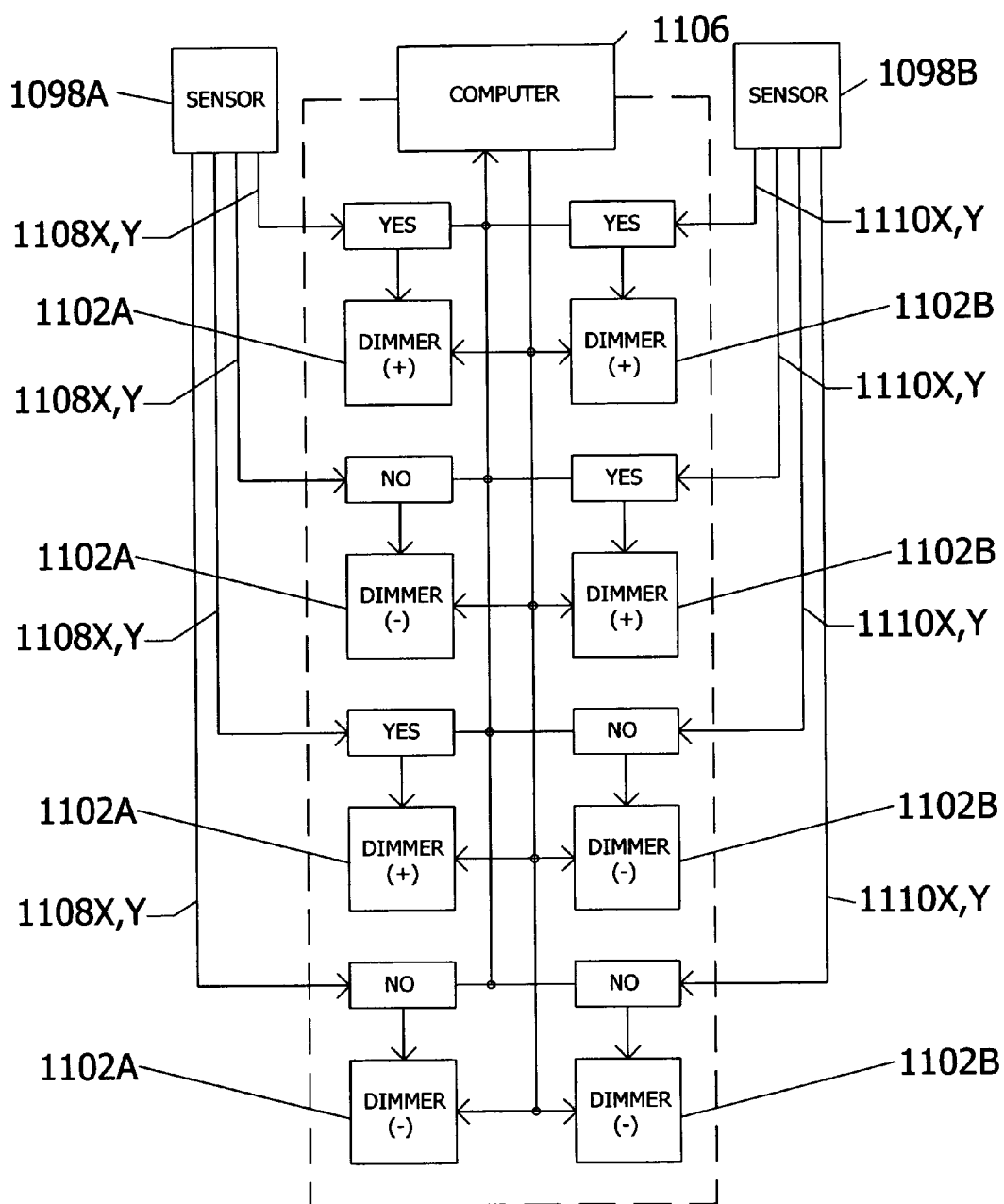


FIG. 76A

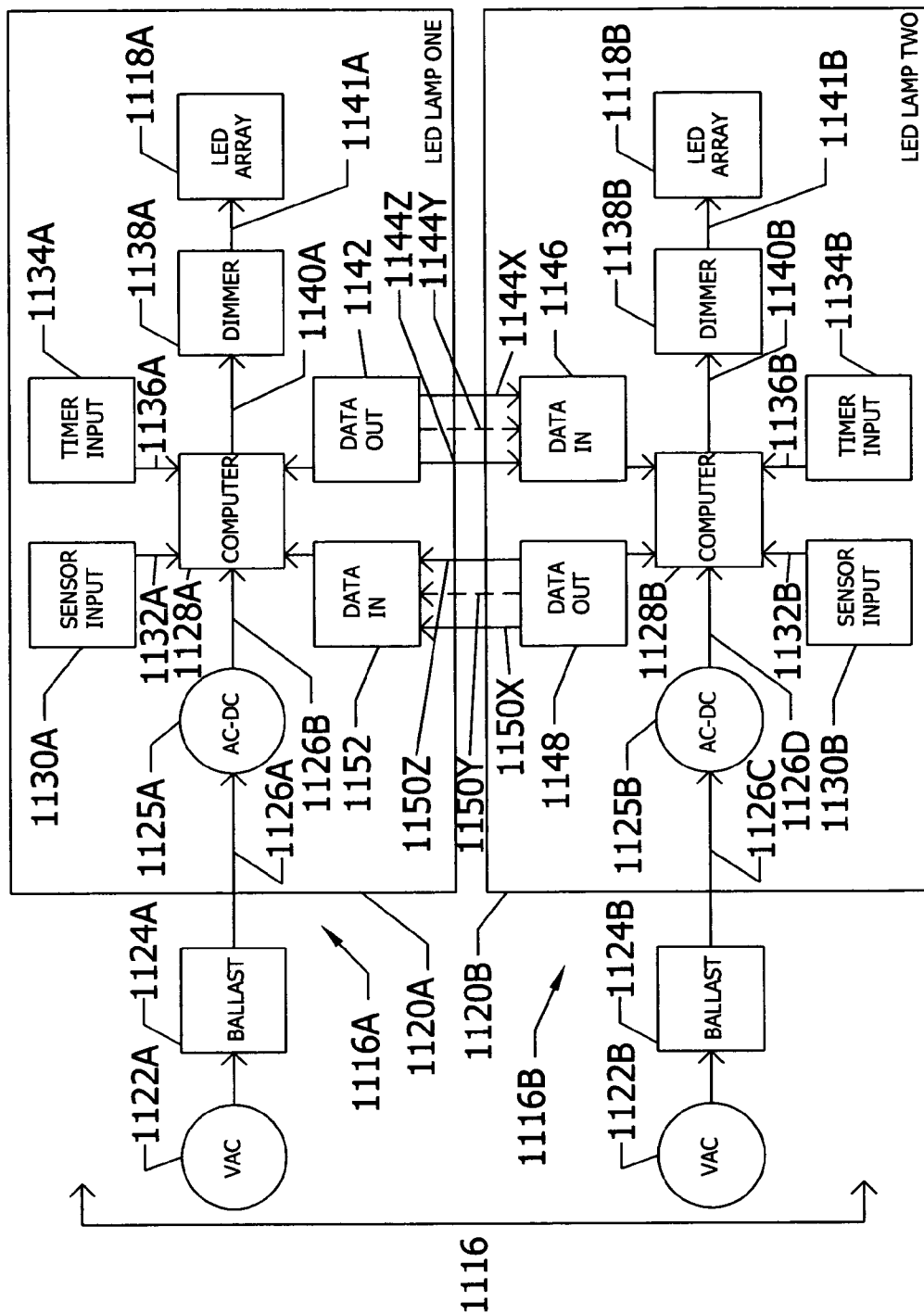


FIG. 77

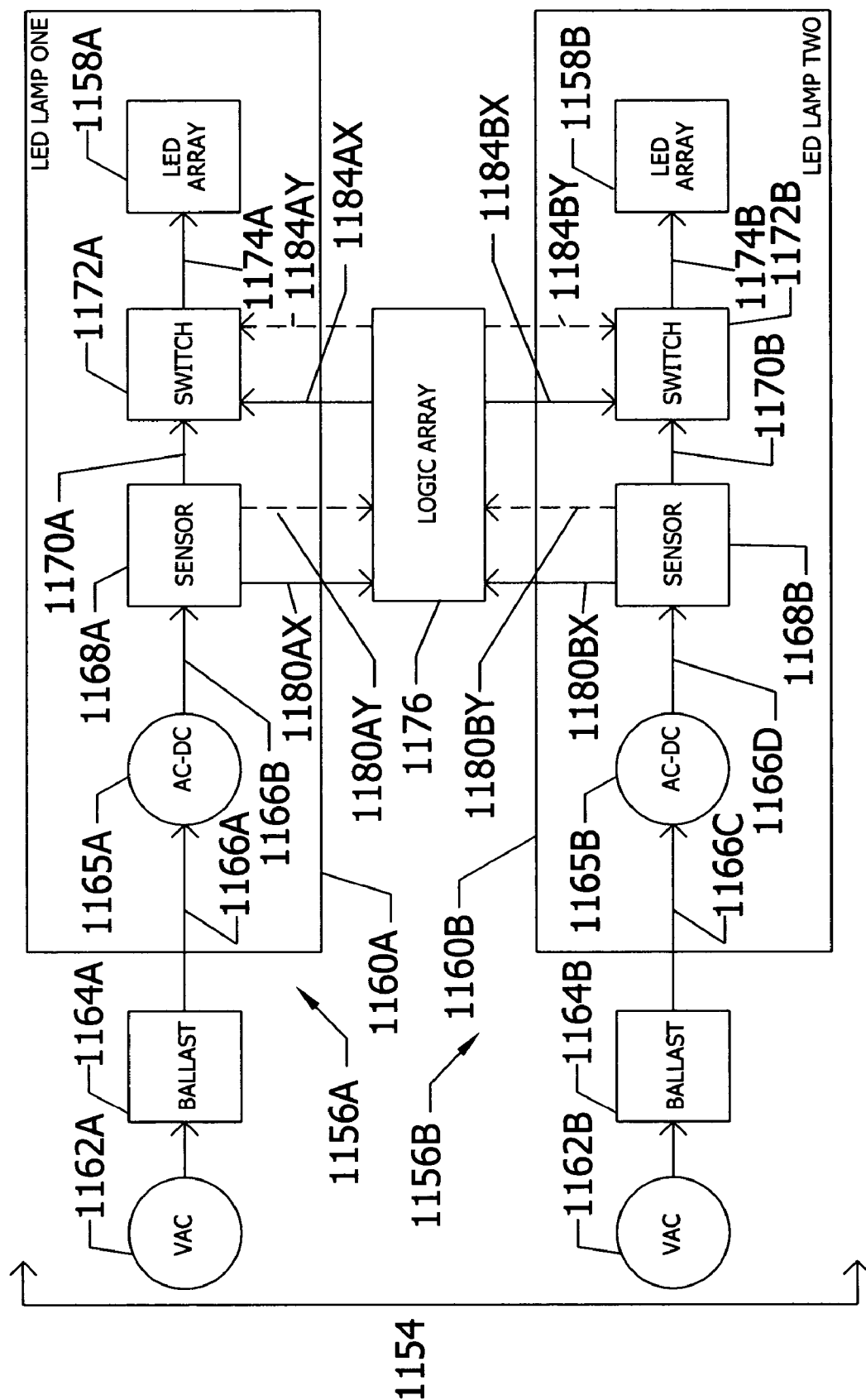


FIG. 78

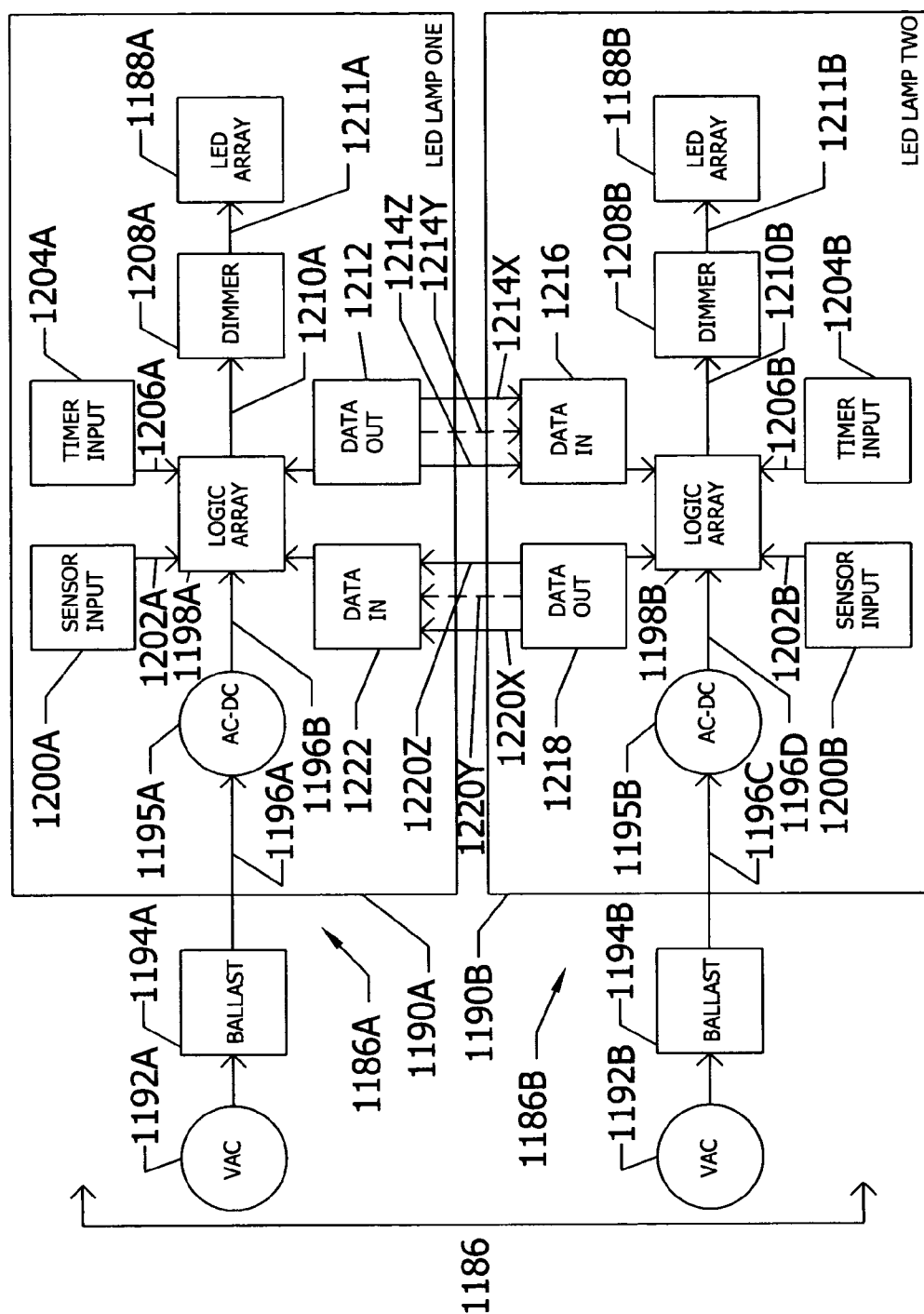


FIG. 78A

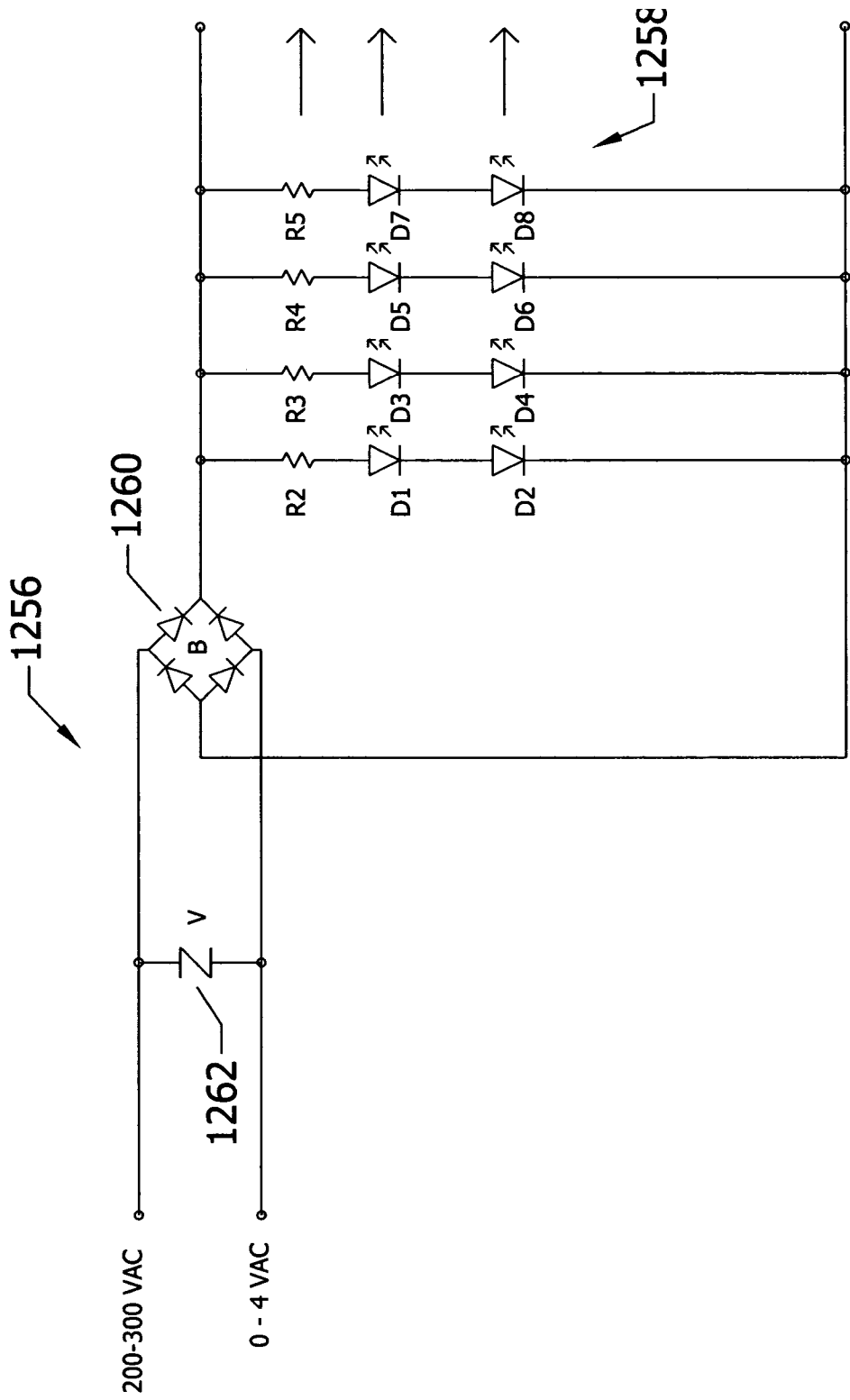


FIG. 79A

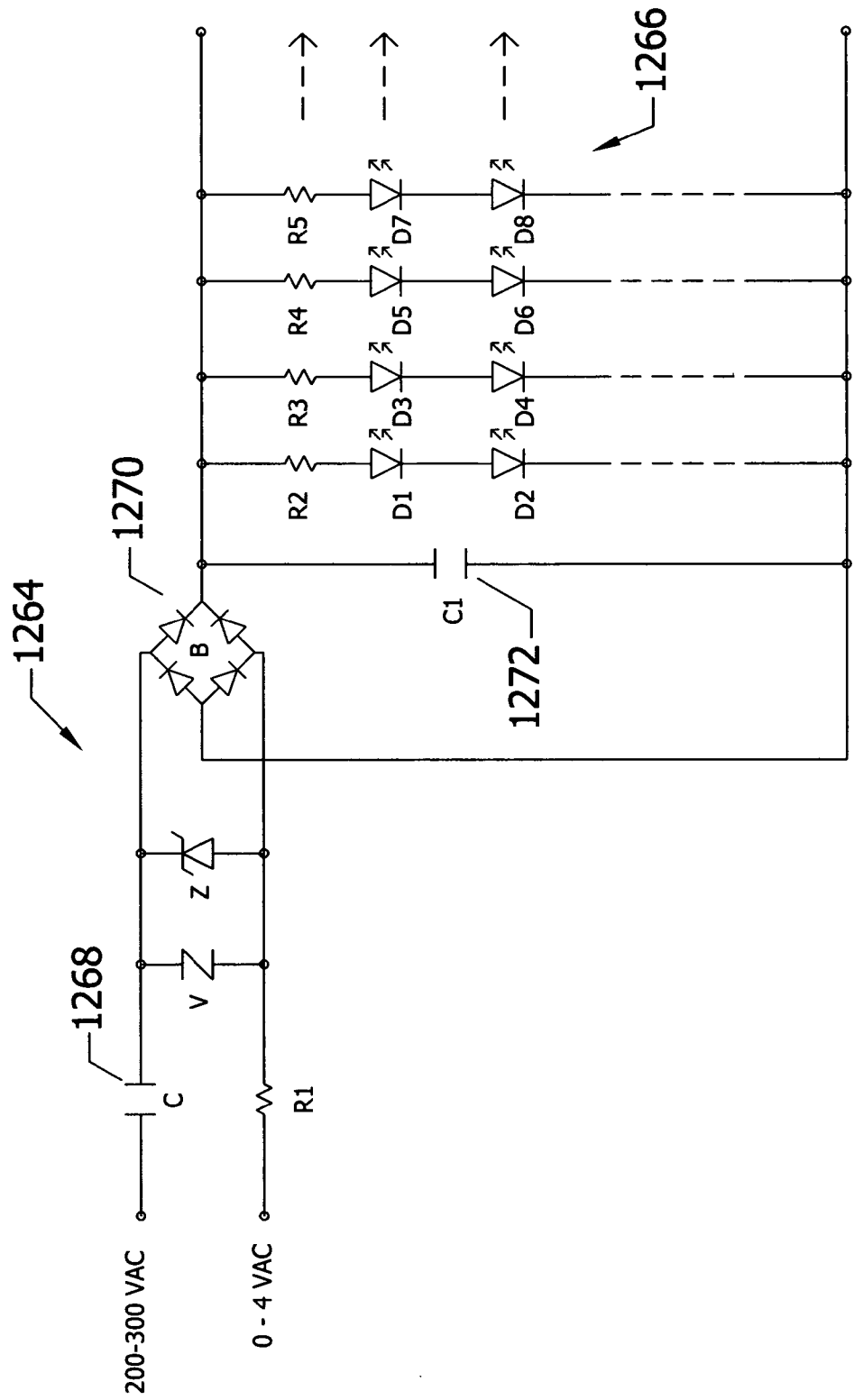


FIG. 79B

POWER CONTROLS FOR TUBE MOUNTED LEDS WITH BALLAST

HISTORY OF THE INVENTION

[0001] This application is a continuation-in-part (CIP) of U.S. Pat. No. 6,853,151, which is a continuation-in-part (CIP) of U.S. Pat. No. 6,762,562.

FIELD OF THE INVENTION

[0002] The present invention relates to tubular lamps having LED arrays with ballasts.

BACKGROUND OF THE INVENTION

[0003] U.S. Pat. No. 6,762,562 and U.S. Pat. No. 6,853,151 both set forth LED arrays positioned in tubes that are powered by reduced voltage from a ballast. This reduced voltage can be provided with various controls positioned in the tubes so that the illumination from the LED arrays can be varied or switched to an on or off mode in accordance with illumination requirements that are independent of the main AC voltage lines in the area of the LED lamp.

[0004] With the present energy crisis, it becomes evident that the need for more energy efficient lamps of all configurations need to be developed and implemented as soon as possible for energy conservation.

[0005] Many private, public, commercial and office buildings including transportation vehicles like trains and buses use fluorescent lamps installed in lighting fixtures. Fluorescent lamps are presently much more efficient than incandescent lamps in using energy to create light. Rather than applying current to a wire filament to produce light, fluorescent lamps rely upon an electrical arc passing between two electrodes, one located at either ends of the lamp. The arc is conducted by mixing vaporized mercury with purified gases, mainly Neon and Krypton or Argon gas inside a tube lined with phosphor. The mercury vapor arc generates ultraviolet energy, which causes the phosphor coating to glow or fluoresce and emit light. Standard electrical lamp sockets are positioned inside the lighting fixtures for securing and powering the fluorescent lamps to provide general lighting.

[0006] Unlike incandescent lamps, fluorescent lamps cannot be directly connected to alternating current power lines. Unless the flow of current is somehow stabilized, more and more current will flow through the lamp until it overheats and eventually destroys itself. The length and diameter of an incandescent lamp's filament wire limits the amount of electrical current passing through the lamp and therefore regulates its light output. The fluorescent lamp, however using primarily an electrical arc instead of a wire filament, needs an additional device called a ballast to regulate and limit the current to stabilize the fluorescent lamp's light output.

[0007] Fluorescent lamps sold in the United States today are available in a wide variety of shapes and sizes. They run from miniature versions rated at 4 watts and 6 inches in length with a diameter of $\frac{5}{8}$ inches, up to 215 watts extending eight feet in length with diameters exceeding 2 inches. The voltage required to start the lamp is dependent on the length of the lamp and the lamp diameter. Larger lamps require higher voltages. Ballast must be specifically

designed to provide the proper starting and operating voltages required by the particular fluorescent lamp.

[0008] In all fluorescent lighting systems today, the ballast performs two basic functions. The first is to provide the proper voltage to establish an arc between the two electrodes, and the second is to provide a controlled amount of electrical energy to heat the lamp electrodes. This is to limit the amount of current to the lamp using a controlled voltage that prevents the lamp from destroying itself.

[0009] Fluorescent ballasts are available in magnetic, hybrid, and the more popular electronic ballasts. Of the electronic ballasts available, there are rapid start and instant start versions. A hybrid ballast combines both electronic and magnetic components in the same package.

[0010] In rapid start ballasts, the ballast applies a low voltage of about four volts across the two pins at either end of the fluorescent lamp. After this voltage is applied for at least one half of a second, an arc is struck across the lamp by the ballast starting voltage. After the lamp is ignited, the arc voltage is reduced to the proper operating voltage so that the current is limited through the fluorescent lamp.

[0011] Instant start ballasts on the other hand, provide light within $\frac{1}{10}$ of a second after voltage is applied to the fluorescent lamp. Since there is no filament heating voltage used in instant start ballasts, these ballasts require about two watts less per lamp to operate than do rapid start ballasts. The electronic ballast operates the lamp at a frequency of 20,000 Hz or greater, versus the 60 Hz operation of magnetic and hybrid type ballasts. The higher frequency allows users to take advantage of increased fluorescent lamp efficiencies, resulting in smaller, lighter, and quieter ballast designs over the standard electromagnetic ballast.

[0012] Existing fluorescent lamps today use small amounts of mercury in their manufacturing process. The United States Environmental Protection Agency's (EPA) Toxicity Characteristic Leaching Procedure (TCLP) is used by the Federal Government and most states to determine whether or not used fluorescent lamps should be characterized as hazardous waste. It is a test developed by the EPA in 1990 to measure hazardous substances that might dissolve into the ecosystem. Some states use additional tests or criteria and a few have legislated or regulated that all fluorescent lamps are hazardous whether or not they pass the various tests. For those states that use TCLP to determine the status of linear fluorescent lamps, the mercury content is the critical factor. In order to minimize variability in the test, the National Electrical Manufacturers Association (NEMA) developed a standard on how to perform TCLP testing on linear fluorescent lamps (NEMA Standards Publication LL1-1997).

[0013] The TCLP attempts to simulate the effect of disposal in a conventional landfill under the complex conditions of acid rain. Briefly, TCLP testing of fluorescent lamps consists of the following steps:

[0014] 1. All lamp parts are crushed or cut into small pieces to ensure all potential hazardous materials will leach out in the test.

[0015] 2. The lamp parts are put into a container and an acetic acid buffer with a pH of 5 is added. A slightly acidic extraction fluid is used to represent typical landfill extraction conditions.

[0016] 3. The closed container is tumbled end-over-end for 18 hours at 30 revolutions per minute.

[0017] 4. The extraction fluid is then filtered and the mercury that is dissolved in the extraction fluid is measured per liter of liquid.

[0018] The average test result must be lower than 0.2 milligrams of mercury per liter of extraction fluid for the lamp to be qualified as non-hazardous waste. Items that pass the TCLP described above are TCLP-compliant, are considered non-hazardous by the EPA, and are exempt from the Universal Waste Ruling (UWR). Four-foot long fluorescent lamps with more than 6 milligrams of mercury, for example, fail the TCLP without an additive. The UWR is the part of the EPA's Resource Conservation and Recovery Act (RCRA), which governs the handling of hazardous waste. The UWR was established in May 1995 to simplify procedures for the handling, disposal, and recycling of batteries, pesticides, and thermostats, all considered widespread sources of low-level toxic waste. The purpose was to reduce the cost of complying with the more stringent hazardous waste regulations while maintaining environmental safeguards. Lamps containing mercury and lead were not included in the UWR. Originally, in most states, users disposing more than 350 lamps a month were required to comply with the more stringent government regulations. In Jul. 6, 1999 the EPA added non-TCLP-compliant lamps like those containing lead and mercury to the UWR. This addition went into effect in Jan. 6, 2000. So lamps that pass the TCLP are exempt from the UWR.

[0019] Not all states comply with the UWR after Jan. 6, 2000. Individual states have a choice of adopting the UWR for lamps or keeping the original RCRA full hazardous waste regulation. States can elect to impose stricter requirements than the federal government, which is what California has done with its TTLC or Total Threshold Limit Concentration test. In addition to a leaching test, the state of California has a total threshold limit concentration (TTLC) for mercury for hazardous waste qualification. Other states are considering implementing a total mercury threshold as well. California has a more rigorous testing procedure for non-hazardous waste classification. The Total Threshold Limit Concentration (TTLC) also needs to be passed in order for a fluorescent lamp to be classified as non-hazardous waste. The TTLC requires a total mercury concentration of less than 20 weight ppm (parts per million): for example, a F32 T8 lamp with a typical weight of 180 grams must contain less than 3.6 milligrams of mercury. Philips' ALTO lamps were the first fluorescent lamps to pass the Environmental Protection Agency's (EPA) TCLP (Toxic Characteristic Leaching Procedure) test for non-hazardous waste. Philips offers a linear fluorescent lamp range that complies with TTLC and is not hazardous waste in California with other lamp manufacturers following close behind.

[0020] Certain fluorescent lamp manufacturers like General Electric (GE) and Osram-Sylvania (OSI) use additives to legally influence the TCLP test. Different additives can be used. GE puts ascorbic acid and a strong reducing agent into the cement used to fix the lamp caps to the fluorescent lamp ends. OSI mixes copper-carbonate to the cement or applies zinc plated iron lamp end caps. The copper, iron, and zinc ions reduce soluble mercury. These additives are found in fluorescent lamps produced in 1999 and 2000. The use of

additives reduces the soluble mercury measured by the TCLP test in laboratories and is a legitimate way to produce TCLP compliant fluorescent lamps.

[0021] Unfortunately, the additive approach does not reduce or eliminate the amount of hazardous mercury in the environment. More importantly, the additives may not work as effectively in the real world as they do in the laboratory TCLP test. In real world disposal, the lamp end caps are not cut to pass a 0.95 cm sieve, are not tumbled intensively with all other lamp parts for 18 hours, and so forth. Therefore, the additives that becomes available during the TCLP test to reduce mercury leaching may not or only partly, do their job in real world disposal. As a consequence, lamps that rely on additives pass TCLP, but may still have relatively high amounts of mercury leaching out into the environment.

[0022] The TCLP test is a controlled laboratory test meant to represent typical landfill conditions. The EPA developed this test in order to reduce leaching of hazardous materials in the environment. Of course, such a test is a compromise between the practicality of testing a large variety of landfill materials and actual landfill conditions. Not every landfill has a pH of 5 and metal parts are not normally cut into small pieces.

[0023] The amount of mercury that leaches out in real life will depend strongly on the type of additive used and the exact disposal conditions. However, the "additive" approach is not a guarantee that only small amounts of mercury will leach into the environment upon disposal.

[0024] Several states including New Jersey, Delaware, and Arkansas have addressed the additive issue. They have indicated that if lamps with additives were thrown away as non-hazardous waste and are later found to behave differently in the landfill, then the generators and those who dispose of such lamps could potentially face the possibility of having violated the hazardous waste disposal regulation known as RCRA.

[0025] The best fluorescent lamps in production at this time include GE's ECOLUX reduced mercury long-life XL and Philips' ALTO Advantage T8 lamps. They both have a rated lamp life of 24,000 hours, produce 2,950 lumens, and have a Color Rendering Index (CRI) of 85. Rated life for fluorescent lamps is based on a cycle of 3 hours on and 20 minutes off.

[0026] Besides the emission of ultra-violet (UV) rays and the described use of mercury in the manufacture of fluorescent lamps, there are other disadvantages to existing conventional fluorescent lamps that include flickering and limited usage in cold weather environments.

[0027] In conclusion, a particularly useful approach to a safer environment is to have a new lamp that contains no harmful traces of mercury that can leach out in the environment, no matter what the exact disposal conditions are. No mercury lamps are the best option for the environment and for the end-user that desires non-hazardous lamps. Also, no mercury LED retrofitting lamps will free many users from the regulatory burdens such as required paperwork and record keeping, training, and regulated shipping of otherwise hazardous materials. In addition, numerous industrial and commercial facility managers will no longer be burdened with the costs and hassles of disposing large numbers of spent fluorescent lamps considered as hazardous waste.

The need for a safer, energy efficient, reliable, versatile, and less maintenance light source is needed.

[0028] Light emitting diode (LED) lamps and organic light emitting diode (OLED) lamps that retrofit fluorescent lighting fixtures using existing ballasts, or other power supplies can help to relieve some of the above power and environmental problems.

[0029] An organic light emitting diode or OLED is an electronic device made by placing a series of extremely thin layers of organic film material between two conductors. The conductors can be glass substrate or flexible plastic material. When electrical current is applied, these organic film materials emit bright light. This process is called electro-phosphorescence. Even with the layered configuration, OLEDs are very thin, usually less than 500 nm or 0.5 thousandths of a millimeter. OLED displays offer up to 165 degrees viewing and require only 2-10 volts to operate while OLED panels may also be used as lighting devices. An alternative name for OLED technology is OEL or Organic Electro-Luminescence.

[0030] Recent advances made by GE Lighting in the first quarter of 2004 have produced a very bright 24 square inch OLED panel producing well over 1200 lumens of light with an efficacy of 15 lumens per watt and a power consumption of about 80-watts. This latest breakthrough demonstrates that the light quality, output, and efficiency of OLED technology can meet the needs of general illumination on par with todays incandescent and possibly fluorescent lamp technologies. Because OLED panels are thinner, lighter, and flexible by nature, it serves as a possible light source for the present invention.

[0031] In the present CIP application, the use of "LED" covers both conventional high-brightness semiconductor light emitting diodes (LEDs) and organic light emitting diodes (OLEDs); semiconductor dies that produce light in response to current, light emitting polymers, electro-luminescent strips (EL), etc. Furthermore, the use of "LED" may refer to a single light-emitting device having multiple semiconductor dies that are individually controlled. It should also be understood that the use of "LED" does not restrict the package type of an LED. The use of "LED" may refer to packaged LEDs, non-packaged LEDs, surface mount LEDs, chip-on-board (COB) LEDs, and LEDs of all other configurations. The use of "LED" also includes LEDs packaged or associated with phosphor, wherein the phosphor may convert radiant energy emitted from the LED to a different wavelength of light. The use of "LED" will also include high-brightness white LEDs as well as high-brightness color LEDs in different packages. An LED array can consist of at least one LED or a plurality of LEDs, and at least one LED array can also consist of a plurality of LED arrays.

[0032] These new LED lamps can be used with magnetic, hybrid, and electronic instant and rapid start ballasts, and will plug directly into the present sockets thereby replacing the fluorescent lamps in existing lighting fixtures or with other AC or DC power supplies. The new LED retrofit lamps are adapted to be inserted into the housing of existing fluorescent lighting fixtures acting as a direct replacement light unit for the fluorescent lamps of the original equipment. The major advantage is that the new LED retrofit lamps with integral electronic circuitry are able to replace existing fluorescent lamps without any need to remove the installed

ballasts or make modifications to the internal wiring of the already installed fluorescent lighting fixtures. The new LED retrofit lamps include replacing linear cylindrical tube T8 and T12 lamps, U-shape curved lamps, circular T5 lamps, helical CFL compact type fluorescent and PL lamps, and other tubular shaped fluorescent lamps with two or more electrical contacts that mate with existing sockets.

[0033] The use of light emitting diodes and organic light emitting diodes as alternate light sources to replace existing lamp designs is a viable option. Light Emitting Diodes (LEDs) are compound semiconductor devices that convert electricity to light when biased in the forward direction. In 1969, General Electric invented the first LED, SSL1 (Solid State Lamp). The SSL1 was a gallium phosphide device that had transistor-like properties i.e. high shock, vibration resistance and long life. Because of its small size, ruggedness, fast switching, low power and compatibility with integrated circuitry, the SSL1 was developed for many indicator-type applications. It was these unique advantages over existing light sources that made the SSL1 find its way into many future applications.

[0034] Today advanced high-brightness LEDs and OLEDs are the next generation of lighting technology that is currently being installed in a variety of lighting applications. As a result of breakthroughs in material efficiencies and optoelectronic packaging design, LEDs are no longer used as just indicator lamps. They are now used as a light source for the illumination of monochromatic applications such as traffic signals, vehicle brake lights, and commercial signs.

[0035] In addition, white light LED technology will change the lighting industry, as we know it. Even with further improvements in color quality and performance, white light LED technology has the potential to be a dominant force in the general illumination market. LED benefits include: energy efficiency, compact size, low wattage, low heat, long life, extreme robustness and durability, little or no UV emission, no harmful mercury, and full compatibility with the use of integrated circuits.

[0036] To reduce electrical cost and to increase reliability, LED lamps have been developed to replace the conventional incandescent lamps typically used in existing general lighting fixtures. LED lamps consume less energy than conventional lamps and give much longer lamp life.

[0037] Unfortunately, the prior art LED lamp designs used thus far still do not provide sufficiently bright and uniform illumination for general lighting applications, nor can they be used strictly as direct and simple LED retrofit lamps for existing fluorescent lighting fixtures and ballast configurations.

[0038] U.S. Pat. No. D366,506 issued to Lodhie on Jan. 19, 1999, and U.S. Pat. No. D405,201 issued to Lodhie on Feb. 2, 1999, both disclose an ornamental design for a bulb. One has a bayonet base and the other a medium screw base, but neither was designed exclusively for use as a retrofit lamp for a fluorescent lighting fixture using the existing fluorescent sockets and ballast electronics. Power to the circuit boards and light emitting diodes are provided on one end only. Fluorescent ballasts can provide power on at least one end, but normally power to the lamp is supplied into two ends. Likewise, U.S. Pat. No. 5,463,280 issued to Johnson, U.S. Pat. No. 5,655,830 issued to Ruskouski, and U.S. Pat.

No. 5,726,535 issued to Yan, all disclose LED Retrofit lamps exclusively for exit signs and the like. But as mentioned before, none of the disclosed retrofit lamps are designed for use as a retrofit lamp for a fluorescent lighting fixture using the existing fluorescent sockets and ballast electronics. Power to the circuit boards and light emitting diodes are provided on one end only while existing fluorescent ballasts can provide power on two ends of a lamp.

[0039] U.S. Pat. No. 5,577,832 issued to Lodhie on Nov. 26, 1996, teaches a multilayer LED assembly that is used as a replacement light for equipment used in manufacturing environments. Although the multiple LEDs, which are mounted perpendicular to a base provides better light distribution, this invention was not exclusively designed for use as a retrofit lamp for fluorescent lighting fixtures using the existing fluorescent sockets and ballast electronics. In addition, this invention was designed with a single base for powering and supporting the LED array with a knob coupled to an axle attached to the base on the opposite end. The LED array of the present invention is not supported by the lamp base, but is supported by the tubular housing itself. The present invention provides power on both ends of the retrofit LED lamp serving as a true replacement lamp for existing fluorescent lighting fixtures.

[0040] U.S. Pat. No. 5,688,042 issued to Madadi on Nov. 18, 1997, discloses LED lamps for use in lighted sign assemblies. The invention uses three flat elongated circuit boards arranged in a triangular formation with light emitting diodes mounted and facing outward from the center. This configuration has its limitation, because the light output is not evenly distributed away from the center. This LED lamp projects the light of the LEDs in three general zonal directions. Likewise, power to the LEDs is provided on one end only. In addition, the disclosed configuration of the LEDs limits its use in non-linear and curved housings.

[0041] U.S. Pat. No. 5,949,347 issued to Wu on Sep. 7, 1999, also discloses a retrofit lamp for illuminated signs. In this example, the LEDs are arranged on a shaped frame, so that they are aimed in a desired direction to provide bright and uniform illumination. But similar to Madadi et al, this invention does not provide for an omni-directional and even distribution of light as will be disclosed by the present invention. Again, power to the LEDs is provided on one end of the lamp only and cannot be used in either non-linear or curved housings.

[0042] U.S. Pat. No. 5,575,459 issued to Anderson on Nov. 19, 1996, U.S. Pat. No. 6,471,388 B1 issued to Marsh on Oct. 29, 2002, and U.S. Pat. No. 6,520,655 B2 issued to Ohuchi on Feb. 18, 2003 all contain information that relate to replacement LED lamps, but do not disclose the detailed specifics of the original invention.

[0043] The following list of U.S. patents and patent applications is made of record and presented for background reference as being related to the present invention disclosure.

[0044] U.S. Patent Application No. 2004/0032220A1 by Cok et al. published on Feb. 19, 2004 relates to an OLED lamp.

[0045] U.S. Pat. No. 5,811,942 issued to Pedretti on Sep. 22, 1998, and U.S. Pat. No. 6,608,453B2 issued to Morgan

et al. on Aug. 19, 2003, both patents disclose computer-based control of lighting systems.

[0046] The present invention has been made in order to solve the problems that have arisen in the course of an attempt to develop energy efficient lamps. This invention is designed to replace the existing hazardous fluorescent lamps that contain harmful mercury and emit dangerous ultraviolet rays. They can be used directly in existing sockets and lighting fixtures without the need to change or remove the existing fluorescent lamp ballasts or wiring.

[0047] A primary object of the present invention is to provide a LED lamp that will bring about more energy conservation and savings.

SUMMARY OF THE INVENTION

[0048] The present continuation-in-part application discloses a power saving device that includes a fluorescent luminaire having a ballast assembly and LEDs positioned within a tube and electrical power delivered from the ballast assembly to the LEDs. The LED lamp includes means for controlling the delivery of the electrical power from the ballast assembly to the LEDs wherein the use of electrical power can be reduced or eliminated automatically during periods of non-use. Such means for controlling can include an on-off switch mounted in the tube or can also include a dimmer current driver mounted in the tube that regulates the amount of power delivered to the LEDs. A computer or an array of logic arrays can control the dimmer or switches to the LED arrays. A sensor such as an occupancy motion detection sensor mounted external to the tube or within the tube can send signals to the computer, logic arrays, or switches. Two or more such LED lamps with one or more computers in network communication with the sensors can be controlled so as to reduce flickering between lamps when illumination areas are being alternately occupied. Preset or manually set timers can control the switch or be used in combination with the computer, logic arrays, switch, and dimmer.

[0049] The present invention solves the aforementioned problems with prior inventions by providing an LED lamp that has a main, generally tubular housing terminating at both ends in a lamp base that inserts directly into the lamp socket of existing fluorescent lighting fixtures used for general lighting in public, private, commercial, industrial, residential buildings, and even in transportation vehicles. The new LED lamps include replacing linear cylindrical tube T8 and T12 lamps, U-shape curved lamps, circular T5 lamps, and CFL compact type fluorescent and PL lamps, etc. The main outer tubular housing of the new LED lamps can be linear, U-shaped, circular, or helical in configuration. It can be manufactured as a single hollow housing or as two halves that can be combined to form a single hollow housing. The two halves can be designed to snap together, or can be held together with glue, or by other means like ultrasonic welding, etc. The main outer tubular housing can be made of a light transmitting material like glass or acrylic plastic for example. The surface of the main outer tubular housing can be diffused or can be coated with a white translucent film to create a more dispersed light output similar to present fluorescent lamps. Power to the LED lamps in the various shapes and configurations is provided at the two ends by existing fluorescent ballasts. Integral

electronic circuitry converts the power from the fluorescent ballasts necessary to power the LEDs mounted to the circuit boards that are inserted within the main outer tubular housing. Desirably, the two base end caps of the LED lamp have apertures therein to allow air to pass through into and out from the interior of the main outer tubular housing and integral electronic circuitry.

[0050] In one embodiment of the present invention, the discrete or surface mount LEDs are compactly arranged and fixedly mounted with lead-free solder onto a flat rectangular flexible circuit board made of a high-temperature polyimide or equivalent material. There are long slits between each column and row of LEDs. The entire flexible circuit board with the attached LEDs is rolled to form a hollow and generally cylindrical frame, with the LEDs facing radially outward from a central axis. Although this embodiment describes a generally cylindrical frame, it can be appreciated by someone skilled in the art to form the flexible circuit board into shapes other than a cylinder, such as an elongated oval, triangle, rectangle, hexagon, octagon, and so on among many other possible configurations. Accordingly, the shape of the tubular housing holding the individual flexible circuit board can be made in a similar shape to match the shape of the formed flexible circuit board. The entire frame is then inserted inside the main outer tubular housing. It can also be said that the shape of the flexible circuit board can be made into the same shape as the tubular housing. The length of the frame is always within the length of the linear main outer tubular housing. AC power generated by the external fluorescent ballast is converted to DC power by additional integral electronics. Electrical connector means are used to connect the integral electronics to the light emitting diode array and to provide current to the LEDs at one or both ends of the flexible circuit board. Since present linear fluorescent lamps are available in one, two, four, six, and eight feet lengths, the flexible circuit board can be designed in increments of one-foot lengths. Individual flexible circuit boards can be cascaded and connected in series to achieve the desired lengths. Likewise, the main outer tubular housing in linear form will be available in the desired lengths, i.e. one, two, four, six, and eight feet lengths. The main outer tubular housing can also be provided in a U-shape, circular, spiral shape, or other curved configuration. The slits provided on the flat flexible circuit board located between each linear array of LEDs allows for the rolled frame to contour and adapt its shape to fit into the curvature of the main outer tubular housing. Such a design allows for the versatile use in almost any shape that the main outer tubular housing can be manufactured in. There is an optional flexible center support that can isolate the integral electronics from the flexible circuit board containing the compact LED array, which may serve as a heat sink to draw heat away from the circuit board and LEDs to the center of the main outer tubular housing and thereby dissipating the heat at the two lamp base ends. There may be cooling holes or air holes on either lamp base end caps of the LED retrofit lamp, in the isolating flexible center support, and in the flexible circuit board containing the compact LED array to allow for proper cooling and airflow. In addition, the main outer tubular housing may contain small holes or other perforations to provide additional cooling of the power electronics, LEDs, and circuit board components. Each end cap of the LED lamp can terminate in single-pin or bi-pin or quad-pin contacts.

[0051] In another embodiment of the present invention, the array of discrete or surface mount LEDs are compactly arranged in a continuously long and thin LED array, and is fixedly mounted with lead-free solder onto a very long and thin flexible circuit board strip made of a high-temperature polyimide or equivalent material. The entire flexible circuit board with the attached LEDs is then spirally wrapped around an optional interior flexible center support. Because the center support is also made of a flexible material like rubber, etc. it can be formed into the shape of a U, a circle, or even into a helical spiral similar to existing CFL or compact fluorescent lamp shapes. The entire generally cylindrical assembly consisting of the compact strip of flexible circuit board spiraling around the center support is then inserted into the main outer tubular housing. Although this embodiment describes a generally cylindrical assembly, it can be appreciated by someone skilled in the art to form the flexible circuit board strip into shapes other than a cylinder, such as an elongated oval, triangle, rectangle, hexagon, octagon, etc. Accordingly, the shape of the tubular housing holding the individual flexible circuit board strip can be made in a similar shape to match the shape of the formed flexible circuit board strip assembly. The length of the entire assembly is always within the length of the main outer tubular housing. AC power generated by the external fluorescent ballasts is converted to DC power by additional integral electronics. Electrical connector means are used to connect the integral electronics to the light emitting diode arrays to provide current to the LEDs at one or both ends of the flexible circuit board. Since present linear fluorescent lamps are available in one, two, four, six, and eight feet lengths, the flexible circuit board can be designed in increments of one-foot lengths. Individual flexible circuit boards can be cascaded and connected in series to achieve the desired lengths. Likewise, the main outer tubular housing in linear form will be available in the desired lengths, i.e. one, two, four, six, and eight feet lengths. Although this embodiment can be used for linear lamps, it can be appreciated by someone skilled in the art for use with curved tubular housings as well. Here, the flexible and hollow center support isolates the integral electronics from the flexible circuit board containing the compact LED array. It can be made of heat conducting material that can also serve as a heat sink to draw heat away from the circuit board and LEDs to the center of the main outer tubular housing and thereby dissipating the heat at the two lamp base ends. There may be cooling holes or air holes on either lamp base end caps of the LED retrofit lamp, in the isolating flexible center support, and in the flexible circuit board containing the compact LED array to allow for proper cooling and airflow. In addition, the main outer tubular housing may contain small holes or other perforations to provide additional cooling of the power electronics, LEDs, and circuit board components. Each end cap of the LED retrofit lamp can terminate in single-pin or bi-pin contacts.

[0052] In yet another embodiment of the present invention, the leads of each discrete LED is bent at a right angle and then compactly arranged and fixedly mounted with lead-free solder along the periphery of a generally round, flat, and rigid circuit board disk. Although this embodiment describes a generally round circular circuit board disk, it can be appreciated by someone skilled in the art to use circuit boards or support structures made in shapes other than a circle, such as an oval, triangle, rectangle, hexagon, octagon,

etc. Accordingly, the shape of the tubular housing holding the individual circuit boards can be made in a similar shape to match the shape of the circuit boards. The circuit board disks are manufactured out of G10 epoxy material, FR4, or other equivalent rigid material. The LEDs in each rigid circuit board disk can be mounted in a direction perpendicular to the rigid circuit board disk, which results in light emanating in a direction perpendicular to the rigid circuit board disk instead of in a direction parallel to the circuit board as described in the previous embodiments. It can also be appreciated by someone skilled in the art to use one or more side emitting LEDs mounted directly to one side of the rigid circuit board disks with adequate heat sinking applied to the LEDs on the same or opposite sides of the rigid circuit board disks. The side emitting LEDs will be mounted in a direction parallel to the rigid circuit board disk, which also results in light emanating in a direction perpendicular to the rigid circuit board disk instead of in a direction parallel to the circuit board as described in the previous embodiments. Each individual rigid circuit board disk is then arranged one adjacent another at preset spacing by grooves provided on the inside surface of the main outer tubular housing that hold the outer rim of the individual circuit boards. The individual circuit boards are connected by electrical transfer means including headers, connectors, and/or discrete wiring that interconnect all the individual LED arrays to two lamp base caps at both ends of the tubular housing. The entire assembly consisting of the rigid circuit board disks with each LED array is inserted into one half of the main outer tubular housing. The main outer tubular housing here can be linear, U-shaped, or round circular halves. Once all the individual rigid circuit board disks and LED arrays are inserted into the grooves provided on the one half of the main outer tubular housing and are electrically interconnected to each other and to the two lamp base ends, the other mating half of the main outer tubular housing is snapped over the first half to complete the entire LED lamp assembly. The length of the entire assembly is always within the length of the main outer tubular housing. AC power generated by the external fluorescent ballasts is converted to DC power by additional integral electronics. Electrical connector means are used to connect the integral electronics to the light emitting diode arrays to provide current to the LEDs at both ends of the complete arrangement of rigid circuit board disks. Since present linear fluorescent lamps are available in one, two, four, six, and eight feet lengths, the rigid circuit board disks can be stacked to form increments of one-foot lengths. Individual rigid circuit board disks can be cascaded and connected in series to achieve the desired lengths. Likewise, the main outer tubular housing in linear form will be available in the desired lengths, i.e. one, two, four, six, and eight feet lengths. Again, this last described embodiment can be used for linear lamps, but it is also suited for curved tubular housings. There may be cooling holes or air holes on either base end caps of the improved LED lamp, and in the individual rigid circuit board disks containing the compact LED array to allow for proper cooling and airflow. In addition, the main outer tubular housing may contain small holes or other perforations to provide additional cooling of the power electronics, LEDs, and circuit board components. Each end cap of the LED lamp can terminate in single-pin or bi-pin or quad-pin contacts.

[0053] It can be appreciated by someone skilled in the art to use a lesser amount of LEDs in the circuit board con-

figurations to project light from an existing fluorescent fixture in the general direction out of the fixture only without any light projected back into the fixture itself. This will allow for lower power consumption, material costs, and will offer greater fixture efficiencies with reduced light losses.

[0054] Ballasts are usually connected to an AC (alternating current) power line operating at 50 Hz or 60 Hz (hertz or cycles per second) depending on the local power company. Most ballast are designed for one of these frequencies, but not both. Some electronic ballast, however, can operate on both frequencies. Also, some ballast are designed to operate on DC (direct current) power. These are considered specialty ballasts for applications like transportation vehicle bus lighting.

[0055] Electromagnetic and hybrid ballasts operate the lamp at the same low frequency as the power line at 50 Hz or 60 Hz. Electronic ballasts operate the lamp at a higher frequency at or above 20,000 Hz to take advantage of the increased lamp efficiency. The fluorescent lamp provides roughly 10% more light when operating at high frequency versus low frequency for the same amount of input power. The typical application, however involves operating the fluorescent lamp at lower input power and high frequency while matching the light output of the lamp at rated power and low frequency. The result is a substantial savings in energy conservation.

[0056] Ballasts can be connected or wired between the input power line and the lamp in a number of configurations. Multiple lamp ballasts for rapid start or instant start lamps can operate lamps connected in series or parallel depending on the ballast design. When lamps are connected in series to a ballast and one lamp fails, or is removed from the fixture, the other lamp(s) connected to that ballast would not light. When the lamps are connected in parallel to a ballast and one lamp fails, or are removed, the other lamp(s) will continue to light.

[0057] As discussed earlier, electronic rapid start fluorescent lamp ballasts apply a low voltage of about 4 volts across the two contact pins at each end of the lamp. After this voltage is applied for at least one half of a second, a high voltage arc is struck across the lamp by the ballast starting voltage. After the lamp ignites, the arc voltage is reduced down to a proper operating voltage and the current is limited through the lamp by the ballast. In the case of electronic instant start fluorescent lamp ballasts, an initial high-voltage arc is struck between the two lamp base ends to ignite the lamp. After the lamp ignites, the arc voltage is again reduced down to a proper operating voltage and the current is limited through the lamp by the ballast. For magnetic type lamp ballasts, a constant voltage is applied to the two lamp base ends to energize and maintain the electrical arc within the fluorescent lamp.

[0058] For standard fluorescent lamps with a filament voltage of about 3.4 volts to 4.5 volts, the minimum starting voltage to ignite the lamp can range from about 108 volts to about 230 volts. For HO or high output fluorescent lamps, the minimum starting voltage is higher from about 110 volts to about 500 volts.

[0059] Given these various voltage considerations, the present invention is designed to work with all existing ballast output configurations. The improved LED lamp does

not require the pre-heating of a filament like a fluorescent lamp and does not need the ignition voltage to function. The circuit is designed so that the electrical contact pins of the two lamp base end caps of the LED lamp may be reversed, or the entire lamp assembly can be swapped end for end and still function correctly similar to a fluorescent lamp. In the preferred electrical design, a single LED circuit board array can be powered by two separate power electronics at either end of the improved LED lamp consisting of bridge rectifiers to convert the AC voltage to DC voltage. Voltage surge absorbers are used to limit the high voltage to a workable voltage, and optional resistor(s) may be used to limit the current seen by the LEDs. The current limiting resistor(s) is purely optional, because the existing fluorescent ballast is already a current limiting device. The resistor(s) then serve as a secondary protection device. In a normal fluorescent lamp and ballast configuration, the ignition voltage travels from one end of the lamp to the other end. In the new and improved LED retrofit lamp, the common or lower potential of both circuits are tied together, and the difference in potential between the two ends will serve as the main direct current or DC voltage potential to drive the LED circuit board array. That is the anode will be the positive potential and the cathode will be the negative potential to provide power to the LEDs. The individual LEDs within the LED circuit board array can be electrically connected in series, in parallel, or in a combination of series and/or parallel configurations.

[0060] In an alternate electrical design for electronic rapid start ballasts; the LED lamp can be electronically designed to work with the initial filament voltage of four volts present on one end of the LED lamp while leaving the other end untouched. The filament voltage is converted through a rectifier circuit or an ac-to-dc converter circuit to provide a DC or direct current voltage to power the LED array. In-line series resistor(s) and/or transistors can be used to limit the current as seen by the LEDs. In addition, a voltage surge absorber or transient voltage suppresser device can be used on the AC input side of the circuit to limit the AC voltage driving the power converter circuit. This electrical design can be used for other types of ballasts as well.

[0061] In yet another alternate electrical design for existing fluorescent ballasts, both ends of the improved LED lamp will have a separate rectifier circuit or ac-to-dc converter circuit as described above. Again, the series resistor(s) and voltage surge absorber(s) can be used. In this arrangement, either end of the improved LED lamp will drive its own independent and separate LED circuit board array. This will allow the improved LED lamp to remain lit if one LED array tends to go out leaving the other on.

[0062] LEDs are now available in colors like Red, Blue, Green, Yellow, Amber, Orange, and many other colors including White. Although any type and color of LED can be used in the LED arrays used on the circuit boards of the present invention, an LED with a wide beam angle will provide a better blending of the light beams from each LED thereby producing an overall generally even distribution of light output omni-directionally and in every position. The use of color LEDs eliminates the need to wrap the fluorescent lamp body in colored gel medium to achieve color dispersions. Color LEDs give the end user more flexibility on output power distribution and color mixing control. The

color mixing controls are necessary to achieve the desired warm tone color temperature and output.

[0063] As an option, the use of a compact array of LEDs strategically arranged in an alternating hexagonal pattern provides the necessary increased number of LEDs resulting in a more even distribution and a brighter output. The minimum number of LEDs used in the array is determined by the total light output required to be at least equivalent to an existing fluorescent lamp that is to be replaced by the improved LED lamp of the present invention.

[0064] Besides using discrete radial mounted 5 mm or 10 mm LEDs, which are readily available from LED manufacturers including Nichia, Lumileds, Gelcore, etc. just to name a few, surface mounted device (SMD) light emitting diodes can be used in some of the embodiments of the present invention mentioned above.

[0065] SMD LEDs are semiconductor devices that have pins or leads that are soldered on the same side that the components sit on. As a result there is no need for feed-through hole passages where solder is applied on both sides of the circuit boards. Therefore, SMD LEDs can be used on single sided boards. They are usually smaller in package size than standard discrete component devices. The beam spread of SMD LEDs is somewhat wider than discrete axial LEDs, yet well less than 360-degree beam spread devices.

[0066] In particular, the Luxeon brand of white SMD (surface mounted device) LEDs can also be used. Luxeon is a product from Lumileds Lighting, LLC a joint venture between Philips Lighting and Hewlett Packard's Agilent Technologies. Luxeon power light source solutions offer huge advantages over conventional lighting and huge advantages over other LED solutions and providers. Lumileds Luxeon technology offers a 17 lumens 1-Watt white LED in an SMD package that operates at 350 mA and 3.2 volts DC, as well as a high flux 120 lumens 5-Watt white LED in a lambertian or a side emitting radiation pattern SMD package that operates at 700 mA and 6.8 volts. Nichia Corporation offers a similarly packaged white output LED with 23 lumens also operating at 350 mA and 3.2 volts. LEDs will continue to increase in brightness within a relatively short period of time.

[0067] In addition, Luxeon now markets a new Luxeon Emitter SMD high-brightness LED that has a special lens in front that bends the light emitted by the LED at right angles and projects the light beam radially perpendicular to the LED center line so as to achieve a light beam having a 360 degree radial coverage. In addition, such a side-emitting radial beam SMD LED has what is designated herein as a high-brightness LED capacity.

[0068] In the past, rigid circuit boards consisted of fiberglass composition called G10 epoxy or FR4 type circuit boards. They did not contain a layer of rigid metal until recently and primarily with the invention of the new high brightness LEDs that needed more heat dissipation. The metal substrate circuit boards or metal core printed circuit boards (MCPCB) were developed and are meant to be attached to a heat sink to further extract heat away from the LEDs. They comprise a circuit layer, a dielectric layer, and a metal base layer.

[0069] The Berquist Co. of Prescott, Wis. offers metal substrate printed circuit boards known by the trade name of

Metal Clad that are made of printed circuit foil having a thickness of 1 oz. to 10 oz. (35-350 m) offering electrical isolation with minimal thermal resistance. These metal substrate circuit boards have a multiple-layer dielectric that bond with the base metal and circuit material. As such, metal substrate circuit boards conduct heat more effectively and efficiently than standard circuit boards. The dielectric layer offers electrical isolation with minimal thermal resistance. As such a heat sink, a cooling fan, or other cooling devices may not be required in certain instances. A multiple-layer dielectric bonds the base metal and circuit metal together. Metal substrate circuit boards are very rigid and can be formed in various shapes such as thin elongated rectangles, circular, and curved configurations.

[0070] There are also ceramic substrate circuit boards, and also a ceramic on metal circuit board called LTCC-M. This new MCPCB technology combines ceramic on metal and is pioneered by Lamina Ceramics located in Westampton, N.J. The ceramic on metal technology in combination with compact arrays of LED dies including Chip on Board or COB technology provides for brighter and more superior thermal performance than some standard MCPCB designs.

[0071] More recently, Lumileds Lighting, LLC now offers a Luxeon warm white LED with a 90 CRI (Color Rendering Index) and 3200 degrees Kelvin CCT (Correlated Color Temperature). Lumileds Luxeon warm white is the first generally available low CCT and high CRI warm white solid-state light source. This new Luxeon LED opens the door for significantly greater use of solid-state illumination in interior and task lighting applications by replicating the soothing, warm feel typically associated with incandescent and halogen lamps. The additional benefit here being the availability of true LED retrofit lamps for existing and new fluorescent lamp fixtures that offer a softer and warmer light output similar to the output produced by incandescent and halogen lamps. An alternate arrangement to get similar CRI and CCT would be to use existing high CCT white color LEDs with a combination of yellow or amber color LEDs to achieve the desired color tone. This lower CCT break through was never available before to the end user with conventional fluorescent lamps unless they used a color film wrap or similar product to "color" the fluorescent lamp light output.

[0072] The described LED retrofit lamp invention can be manufactured in variety of different fluorescent lamp bases, including, but not limited to medium bi-pin base, single-pin base, recessed double contact (DC) base, circline quad-pin base, and PL (bi-pin) base and medium screw base used with compact fluorescents.

[0073] This invention can be summarized as follows: A light emitting diode (LED) lamp for mounting to an existing fixture for a fluorescent lamp having a ballast assembly including ballast opposed electrical contacts, comprising a tubular wall generally circular in cross-section having tubular wall ends, one or more LEDs positioned within the tubular wall between the tubular wall ends. An electrical circuit provides electrical power from the ballast assembly to the LED or LEDs. The electrical circuit includes one or more metal substrate circuit boards and electrically connects the electrical circuit with the ballast assembly. Each supports and holds the LEDs and the LED electrical circuit. The electrical circuit includes an LED electrical circuit including

opposed electrical contacts. At least one electrical string is positioned within the tubular wall and generally extends between the tubular wall ends. The one or more LEDs are in electrical connection with the at least one electrical string, and are positioned to emit light through the tubular wall. Means for suppressing ballast voltage is delivered from the ballast assembly to an LED operating voltage within the voltage design capacity of the at least one LED. The metal substrate circuit board includes opposed means for connecting the metal substrate circuit board to the tubular wall ends, which include means for mounting the means for connecting and the one or more metal substrate circuit boards. The opposed means for connecting the one or more metal substrate circuit boards to the tubular wall ends includes each metal substrate circuit board having opposed tenon connecting ends, and the means for mounting includes each of the tubular wall ends defining a mounting slot, the opposed tenon connecting ends being positioned in the mounting slots. Two or more opposed metal substrate boards each mounting LEDs can be mounted in the tubular wall. It should be noted that the opposed tenon connecting ends can be located not just on each end of the metal substrate circuit board, but can be located just on the opposed ends of the metal base layer of each metal substrate circuit board.

[0074] With the need for energy conservation and savings, smart lighting controls and sensors are used to turn off or dim lighting when there is no one presently occupying a space lit by the lighting. For this reason, one improvement to the present invention allow for added energy conservation and savings by incorporating the smart lighting control and sensors in the LED lamp of the present invention.

[0075] The advantage of each LED lamp having its own sensor ensures each LED lamp operates independent of or together with other LED lamps. For example, there presently exists a problem with occupancy motion sensors. There is usually only one occupancy sensor used to control a bank of lights. Depending on the location of the occupancy sensor, when someone is in the room, but is not noticed by the occupancy sensor either because he or she is out of range or has not moved for a while will either turn the entire bank of lights off, or to cause the bank of lights to dim down to an unusable light level.

[0076] The on board occupancy motion sensor located in each LED lamp of the present invention will trigger the lamp to remain full on when it senses the presence of someone near the LED lamp of the present invention and will turn off or dim the LED lamp when the person exits the room. A timer can be built-in to the electronics or can be pre-programmed for a delay for false trigger conditions.

[0077] Power control modules and other components can be incorporated into the electrical circuits used in the LED lamp of the present invention. The first circuit module may be a dimming module placed in between the DC voltage input to the LED array. This dimming module can take a control input either from a hard-wired sensor like an occupancy motion occupancy sensor, a timer, a computer or from a hand-held or wall mounted remote control box that sends the dimming signal to the dimming module located within the LED lamp. The dimming current driver module will contain the necessary electronics to decipher data input control signals and provide the current driver power to operate the LED arrays. LED current control can be accom-

plished by time and amplitude domain control or other means well known in the arts. The occupancy motion sensor can be preset to dim the LED lamp to perhaps 50% brightness to conserve energy when no one is in a room, for example. The dimming controller can be used to program presets during the day or have a manual adjustment to dim the LED lamp down to full off or anywhere between 0% and 100% brightness. This dimming controller will send the control signal directly to the LED lamp itself and not change the AC voltage to the light fixture like conventional dimmers do. A data control signal to a computer based control system driving the dimming controller can be wireless, including using IR (Infra-Red), RF (Radio-Frequency), WiFi/802.11, FHSS (Frequency Hopping Spread Spectrum, or Bluetooth technology. The data control signal can also be a direct hard-wire connection including DMX512, RS232, Ethernet, DALI, Lonworks, RDM, CEBus Standard EIA-600, X10, and other Power Line Carrier Communication (PLC) protocols.

[0078] Note that existing fluorescent lamps cannot be dimmed below 90% or they will simply go out, while LED lamps can be dimmed down to 0%. Dimmable ballasts presently can only dim the fluorescent lamps by 10%. The bottom line is energy and cost saving. The cost savings comes into play, because the cost of dimmable fluorescent ballasts is usually more than twice the cost of a standard non-dimmable fluorescent ballast, and these dimmable ballasts require a special dimming switch at an additional cost. In addition, savings in lower electrical bills can be significant.

[0079] Another circuit module can be a color effects module for use with color LEDs instead of white LEDs used in the LED lamps. This module allows the LED lamp to change colors. The controllers used for the dimming modules can be modified to achieve the color changing function required here. There will be a minimum of RGB color LEDs, but Amber or A can also be used. The dimming module described hereinbefore used a single channel to dim the entire array of white LEDs, but this circuit module will require 3 or 4 channels of dimming control to achieve different color combinations. Presently, fluorescent lamps use a plastic color wrap to get a colored light. The color changing LED lamp will give a user the ability to achieve more colors without having to stock and change different color wraps to get different desired color light outputs.

[0080] Another circuit module would be a by-pass or feed-thru module that simply bridges the power from the ballast or other power supply straight to the LEDs. The lamp would then function as the LED lamp disclosed in the original parent application and previous CIP application.

[0081] It should be noted that each one or all of the circuit modules mentioned above could be permanently or temporarily mounted for versatility. The use of a microprocessor or CPU and related components including memory RAM and ROM, programming, input and output means, and addressing means need not be required to make the various functions work. The same functions can be accomplished with integrated circuits transistors, switches, and logic arrays etc.

[0082] The present invention will be better understood and the objects and important features, other than those specifically set forth above, will become apparent when consideration is given to the following details and description, which

when taken in conjunction with the annexed drawings, describes, illustrates, and shows preferred embodiments or modifications of the present invention, and what is presently considered and believed to be the best mode of practice in the principles thereof.

DESCRIPTION OF THE DRAWINGS

[0083] FIG. 1 is an elevational side view of a retrofitted single-pin LED lamp mounted to an existing fluorescent fixture having an electronic instant start, hybrid, or magnetic ballast having a pair of single contact electrical socket connectors;

[0084] FIG. 1A is a detailed end view of the LED retrofit lamp taken through line 1A-1A of FIG. 1 showing a single-pin;

[0085] FIG. 2 is an exploded perspective view of the LED retrofit lamp shown in FIG. 1 taken in isolation;

[0086] FIG. 3 is a cross-sectional view of the LED retrofit lamp through a single row of LEDs taken through line 3-3 of FIG. 1;

[0087] FIG. 3A is a detailed mid-sectional cross-sectional view of a single LED of the LEDs shown in FIG. 3 with portions of the tubular wall and LED circuit board but devoid of the optional linear housing;

[0088] FIG. 4 is an overall electrical circuit for the retrofitted LED lamp shown in FIG. 1 wherein the array of LEDs are arranged in an electrical parallel relationship and shown for purposes of exposition in a flat position;

[0089] FIG. 4A is an alternate arrangement of the array of LEDs arranged in an electrical parallel relationship shown for purposes of exposition in a flat position for the overall electrical circuit analogous to the overall electrical circuit shown in FIG. 4 for the LED retrofit lamp;

[0090] FIG. 4B is another alternate arrangement of an array of LEDs arranged in an electrical series relationship shown for purposes of exposition in a flat compressed position for an overall electrical circuit analogous to the electrical circuit shown in FIG. 4 for the LED retrofit lamp;

[0091] FIG. 4C is a simplified arrangement of the array of LEDs shown for purposes of exposition in a flat compressed position for the overall electrical circuit shown in FIG. 4 including lead lines and pin headers and connectors for the LED retrofit lamp;

[0092] FIG. 4D is a simplified arrangement of the array of LEDs shown for purposes of exposition in a flat compressed position for the overall electrical circuit shown in FIG. 4A including lead lines and pin headers and connectors for the LED retrofit lamp;

[0093] FIG. 4E is a simplified arrangement of the array of LEDs shown for purposes of exposition in a flat compressed position for the overall electrical circuit shown in FIG. 4B including lead lines and pin headers and connectors for the LED retrofit lamp;

[0094] FIG. 4F shows a single high-brightness LED positioned on a single string in electrical series arrangement shown for purposes of exposition in a flat compressed mode for the overall electrical circuit shown in FIG. 4 for the retrofit lamp;

[0095] FIG. 4G shows two high-brightness LEDs in an electrical parallel arrangement of two parallel strings with one high-brightness LED positioned on each of the two parallel strings shown for purposes of exposition in a flat compressed mode for the overall electrical circuit shown in FIG. 4 for the retrofit lamp;

[0096] FIG. 5 is a schematic view showing the LED arrays in FIGS. 4 and 4A electrically connected by pin headers and connectors to two opposed integral electronics circuit boards that are electrically connected to base end caps each having a single-pin connection;

[0097] FIG. 6 is a schematic circuit of one of the two integral electronics circuit boards shown in FIG. 5 positioned at one side of the alternating current voltage emanating from the ballast for the LED array shown in FIGS. 4 and 4A;

[0098] FIG. 7 is a schematic circuit of the other of the two integral electronics circuit boards shown in FIG. 5 positioned at the other side of the alternating current voltage emanating from the ballast for the LED array shown in FIGS. 4 and 4A;

[0099] FIG. 8 is an isolated side view of the cylindrical internal support shown in FIGS. 2 and 3;

[0100] FIG. 8A is an end view taken through line 8A-8A in FIG. 8;

[0101] FIG. 9 is a side view of an isolated single-pin end cap shown in FIGS. 1 and 5;

[0102] FIG. 9A is a sectional view taken through line 9A-9A of the end cap shown in FIG. 9;

[0103] FIG. 10 is an alternate sectional view to the sectional view of the LED retrofit lamp taken through a single row of LEDs shown in FIG. 3;

[0104] FIG. 11 is an elevational side view of a retrofitted LED lamp mounted to an existing fluorescent fixture having an electronic rapid start, hybrid, or magnetic ballast having a pair of double contact electrical socket connectors;

[0105] FIG. 11A is a detailed end view of the LED retrofit lamp taken through line 11A-11A of FIG. 11 showing a bi-pin electrical connector;

[0106] FIG. 12 is an exploded perspective view of the LED retrofit lamp shown in FIG. 11 taken in isolation;

[0107] FIG. 13 is a cross-sectional view of the LED retrofit lamp through a single row of LEDs taken through line 13-13 of FIG. 11;

[0108] FIG. 13A is a detailed mid-sectional cross-sectional view of a single LED of the LEDs shown in FIG. 13 with portions of the tubular wall and LED circuit board but devoid of the optional linear housing;

[0109] FIG. 14 is an overall electrical circuit for the retrofitted LED lamp shown in FIG. 11 wherein the array of LEDs are arranged in an electrical parallel relationship and shown for purposes of exposition in a flat position;

[0110] FIG. 14A is an alternate arrangement of the array of LEDs arranged in an electrically parallel relationship shown for purposes of exposition in a flat position for the overall electrical circuit shown in FIG. 14 for the LED retrofit lamp;

[0111] FIG. 14B is another alternate arrangement of the array of LEDs arranged in an electrically parallel relationship shown for purposes of exposition in a flat compressed position for an overall electrical circuit analogous to the overall electrical circuit shown in FIG. 14 for the LED retrofit lamp;

[0112] FIG. 14C is a simplified arrangement of the array of LEDs shown for purposes of exposition in a flat compressed position for the overall electrical circuit shown in FIG. 14 including lead lines and pin headers and connectors for the LED retrofit lamp;

[0113] FIG. 14D is a simplified arrangement of the array of LEDs shown for purposes of exposition in a flat compressed position for the overall electrical circuit shown in FIG. 14A including lead lines and pin headers and connectors for the LED retrofit lamp;

[0114] FIG. 14E is a simplified arrangement of the array of LEDs shown for purposes of exposition in a flat compressed position for the overall electrical circuit shown in FIG. 14B including lead lines and pin headers and connectors for the LED retrofit lamp;

[0115] FIG. 14F shows a single high-brightness LED positioned on a single string in electrical series arrangement shown for purposes of exposition in a flat compressed mode for the overall electrical circuit shown in FIG. 14 for the retrofit lamp;

[0116] FIG. 14G shows two high-brightness LEDs in an electrical parallel arrangement of two parallel strings with one high-brightness LED positioned on each of the two parallel strings shown for purposes of exposition in a flat compressed mode for the overall electrical circuit shown in FIG. 14 for the retrofit lamp;

[0117] FIG. 15 is a schematic view showing the LED array in FIGS. 14 and 14A electrically connected by pin headers and connectors to two opposed integral electronics circuit boards that are electrically connected to base end caps each having a bi-pin connections;

[0118] FIG. 16 is a schematic circuit of one of the two integral electronics circuit boards shown in FIG. 15 positioned at one side of the alternating current voltage emanating from the ballast for the LED array shown in FIGS. 14 and 14A;

[0119] FIG. 17 is a schematic circuit of the other of the two integral electronics circuit boards shown in FIG. 15 positioned at the other side of the alternating current voltage emanating from the ballast for the LED array shown in FIGS. 14 and 14A;

[0120] FIG. 18 is an isolated side view of the cylindrical internal support shown in FIGS. 12 and 13;

[0121] FIG. 18A is an end view taken through line 18A-18A in FIG. 18;

[0122] FIG. 19 is a side view of an isolated bi-pin end cap shown in FIGS. 11 and 15;

[0123] FIG. 19A is a sectional view taken through line 19A-19A of the end cap shown in FIG. 19;

[0124] FIG. 20 is an alternate sectional view to the sectional view of the LED retrofit lamp taken through a single row of LEDs shown in FIG. 13;

[0125] FIG. 21 is top view of a retrofitted semi-circular LED lamp mounted to an existing fluorescent fixture having an electronic rapid start, hybrid, or magnetic ballast;

[0126] FIG. 21A is a view taken through line 21A-21A in FIG. 21;

[0127] FIG. 22 is a top view taken in isolation of the semi-circular circuit board with slits shown in FIG. 21;

[0128] FIG. 23 is a perspective top view taken in isolation of a circuit board in a flat pre-assembly mode with LEDs mounted thereon in a staggered pattern;

[0129] FIG. 24 is a perspective view of the circuit board shown in FIG. 23 in a cylindrically assembled configuration in preparation for mounting into a linear tubular wall;

[0130] FIG. 25 is a partial fragmentary end view of a layered circuit board for a retrofitted LED lamp for a fluorescent lamp showing a typical LED mounted thereto proximate a tubular wall;

[0131] FIG. 26 is an elevational side view of another embodiment of a retrofitted single-pin type LED lamp mounted to an existing fluorescent fixture;

[0132] FIG. 26A is a view taken through line 26A-26A of FIG. 26 showing a single-pin type LED retrofit lamp wherein the existing fluorescent fixture has an electronic instant start, hybrid, or magnetic ballast having a pair of single contact electrical sockets;

[0133] FIG. 27 is an exploded perspective view of the LED retrofit lamp shown in FIG. 26 including the integral electronics taken in isolation;

[0134] FIG. 28 is a sectional top view of the tubular wall taken through line 28-28 in FIG. 26 of a single row of LEDs;

[0135] FIG. 29 is an elongated sectional view of that shown in FIG. 27 taken through plane 29-29 bisecting the cylindrical tube and the disks therein with LEDs mounted thereto;

[0136] FIG. 29A is an alternate elongated sectional view of that shown in FIG. 27 taken through plane 29-29 bisecting the cylindrical tube and the disks therein with a single LED mounted in the center of each disk wherein ten LEDs are arranged in an electrically series relationship;

[0137] FIG. 29B is a simplified arrangement of the array of LEDs shown for purposes of exposition in a flat compressed position for the overall electrical circuit shown in FIG. 29 including lead lines and pin headers for the LED retrofit lamp;

[0138] FIG. 29C is another simplified arrangement of the array of LEDs shown for purposes of exposition in a flat compressed position for the overall electrical circuit shown in FIG. 29 including lead lines and pin headers for the LED retrofit lamp;

[0139] FIG. 29D is a simplified arrangement of the array of LEDs shown for purposes of exposition in a flat compressed position for the overall electrical circuit shown in FIG. 29A including lead lines and pin headers for the LED retrofit lamp;

[0140] FIG. 30 shows a fragmented sectional side view of a portion of two cylindrical support disks and of two LEDs taken from adjoining LED rows as indicated in FIG. 29 and

further showing electrical connections between the LEDs as related to the LED retrofit lamp of FIG. 26;

[0141] FIG. 30A shows an alternate fragmented sectional side view of a portion of two cylindrical support disks and of a single LED centrally mounted to each cylindrical support disks taken from adjoining LED rows as indicated in FIG. 29 and further showing electrical connections between the LEDs as related to the LED retrofit lamp of FIG. 26;

[0142] FIG. 30B is an isolated top view of the 6-wire electrical connectors and headers shown in side view in FIG. 30;

[0143] FIG. 31 is a schematic view showing the LED array in FIGS. 26 and 27 electrically connected by pin connectors to two opposed integral electronics circuit boards that are electrically connected to base end caps each having a single-pin connection;

[0144] FIG. 32 is a schematic circuit of one of the two integral electronics circuit boards shown in FIG. 31 positioned at one side of the alternating current voltage emanating from the ballast for the LED array shown in FIG. 31;

[0145] FIG. 33 is a schematic circuit of the other of the two integral electronics circuit boards shown in FIG. 31 positioned at the other side of the alternating current voltage emanating from the ballast for the LED array shown in FIG. 31;

[0146] FIG. 34 shows a full frontal view of a single support disk as related to the LED retrofit lamp shown in FIG. 26 taken in isolation with an electrical schematic rendering showing a single row of ten LEDs connected in series within an electrical string as a part of the total parallel electrical structure for the LEDs;

[0147] FIG. 34A shows a full frontal view of a single support disk as related to the LED retrofit lamp shown in FIG. 26 taken in isolation with an electrical schematic rendering showing a single LED to be connected in series within an electrical string as a part of the total parallel electrical structure for the LEDs;

[0148] FIG. 35 is a side view of an isolated single-pin end cap of those shown in FIGS. 26 and 27;

[0149] FIG. 35A is a sectional view taken through line 35A-35A of the end cap shown in FIG. 35;

[0150] FIG. 36 is an elevational side view of another embodiment of a retrofitted bi-pin LED lamp mounted to an existing fluorescent fixture;

[0151] FIG. 36A is a view taken through line 36A-36A of FIG. 36 showing a bi-pin type LED retrofit lamp wherein the existing fluorescent fixture has an electronic rapid start, hybrid, or magnetic ballast having a pair of double contact electrical sockets;

[0152] FIG. 37 is an exploded perspective view of the LED retrofit lamp shown in FIG. 36 including the integral electronics taken in isolation;

[0153] FIG. 38 is a sectional top view of the tubular wall taken through line 38-38 in FIG. 36 of a single row of LEDs;

[0154] FIG. 39 is an elongated sectional view of the LED retrofit lamp shown in FIG. 37 taken through plane 39-39 bisecting the cylindrical tube and the disks therein with LEDs mounted thereto;

[0155] FIG. 39A is an alternate elongated sectional view of that shown in FIG. 37 taken through plane 39-39 bisecting the cylindrical tube and the disks therein with a single LED mounted in the center thereto;

[0156] FIG. 39B is a simplified arrangement of the array of LEDs shown for purposes of exposition in a flat compressed position for the overall electrical circuit shown in FIG. 39 including lead lines and pin headers for the LED retrofit lamp;

[0157] FIG. 39C is a simplified arrangement of the array of LEDs shown for purposes of exposition in a flat compressed position for the overall electrical circuit shown in FIG. 39 including lead lines and pin headers for the LED retrofit lamp;

[0158] FIG. 39D is a simplified arrangement of the array of LEDs shown for purposes of exposition in a flat compressed position for the overall electrical circuit shown in FIG. 39A including lead lines and pin headers for the LED retrofit lamp;

[0159] FIG. 40 shows a fragmented sectional side view of a portion of two cylindrical support disks and of two LEDs taken from adjoining LED rows as indicated in FIG. 39, and further showing electrical connections between the LEDs as related to the LED retrofit lamp of FIG. 36;

[0160] FIG. 40A shows an alternate fragmented sectional side view of a portion of two cylindrical support disks and of a single LED centrally mounted to each cylindrical support disks taken from adjoining LED rows as indicated in FIG. 39, and further showing electrical connections between the LEDs as related to the LED retrofit lamp of FIG. 36;

[0161] FIG. 40B is an isolated top view of the 6-wire electrical connectors and headers shown in side view in FIG. 40;

[0162] FIG. 41 is a schematic view showing the LED array in FIGS. 36 and 37 electrically connected by pin connectors to two opposed integral electronics circuit boards that are electrically connected to base end caps each having a bi-pin connections;

[0163] FIG. 42 is a schematic circuit of one of the two integral electronics circuit boards shown in FIG. 41 positioned at one side of the alternating current voltage emanating from the ballast for the LED array shown in FIG. 41;

[0164] FIG. 43 is a schematic circuit of the other of the two integral electronics circuit boards shown in FIG. 41 positioned at the other side of the alternating current voltage emanating from the ballast for the LED array shown in FIG. 41;

[0165] FIG. 44 shows a full frontal view of a single support disk as related to the LED retrofit lamp shown in FIG. 36 taken in isolation with an electrical schematic rendering showing a single row of ten LEDs connected in series within an electrical string as a part of the total parallel electrical structure for the LEDs;

[0166] FIG. 44A shows a full frontal view of a single support disk as related to the LED retrofit lamp shown in FIG. 36 taken in isolation with an electrical schematic rendering showing a single LED to be connected in series within an electrical string as a part of the total parallel electrical structure for the LEDs;

[0167] FIG. 45 is a side view of an isolated bi-pin end cap shown in FIGS. 36 and 37;

[0168] FIG. 45A is a sectional view taken through line 45A-45A of the end cap shown in FIG. 45;

[0169] FIG. 46 is a fragment of a curved portion of an LED retrofit lamp showing disks in the curved portion;

[0170] FIG. 47 is a simplified cross-section of a tubular housing as related to FIG. 1 devoid of light emitting diodes with a self-biased circuit board mounted therein with both the tubular housing and circuit board being oval in cross-section;

[0171] FIG. 47A is a simplified cross-section of a tubular housing as related to FIG. 1 devoid of light emitting diodes with a self-biased circuit board mounted therein with both the tubular housing and circuit board being triangular in cross-section;

[0172] FIG. 47B is a simplified cross-section of a tubular housing as related to FIG. 1 devoid of light emitting diodes with a self-biased circuit board mounted therein with both the tubular housing and circuit board being rectangular in cross-section;

[0173] FIG. 47C is a simplified cross-section of a tubular housing as related to FIG. 1 devoid of light emitting diodes with a self-biased circuit board mounted therein with both the tubular housing and circuit board being hexagonal in cross-section;

[0174] FIG. 47D is a simplified cross-section of a tubular housing as related to FIG. 1 devoid of light emitting diodes with a self-biased circuit board mounted therein with both the tubular housing and circuit board being octagonal in cross-section;

[0175] FIG. 48 is a simplified cross-section of a tubular housing as related to FIG. 26 devoid of light emitting diodes with a support structure mounted therein with both the tubular housing and support structure being oval in cross-section;

[0176] FIG. 48A is a simplified cross-section of a tubular housing as related to FIG. 26 devoid of light emitting diodes with a support structure mounted therein with both the tubular housing and support structure being triangular in cross-section;

[0177] FIG. 48B is a simplified cross-section of a tubular housing as related to FIG. 26 devoid of light emitting diodes with a support structure mounted therein with both the tubular housing and support structure being rectangular in cross-section;

[0178] FIG. 48C is a simplified cross-section of a tubular housing as related to FIG. 26 devoid of light emitting diodes with a support structure mounted therein with both the tubular housing and support structure being hexagonal in cross-section;

[0179] FIG. 48D is a simplified cross-section of a tubular housing as related to FIG. 26 devoid of light emitting diodes with a support structure mounted therein with both the tubular housing and support structure being octagonal in cross-section;

[0180] FIG. 49 is a simplified cross-view of a support structure positioned in a tubular housing with a single high-brightness SMD LED mounted to the center of the support;

[0181] FIG. 50 is a side view of the alternate retrofitted single-pin LED lamp mounted to an existing fluorescent fixture having an electronic instant start, hybrid, or magnetic ballast having a pair of single contact electrical socket connectors;

[0182] FIG. 50A is a detailed end view of the alternate LED retrofit lamp taken through line 50A-50A of FIG. 50 showing a single-pin;

[0183] FIG. 51 is an exploded perspective view of the alternate LED retrofit lamp shown in FIG. 50 taken in isolation;

[0184] FIG. 52 is a cross-sectional view of the alternate LED retrofit lamp through a single row of LEDs taken through line 52-52 of FIG. 50;

[0185] FIG. 52A is a detailed mid-sectional cross-sectional view of a single LED of the LEDs shown in FIG. 52 with portions of the tubular wall and LED circuit board;

[0186] FIG. 53 is an overall electrical circuit for the alternate retrofitted LED lamp shown in FIG. 50 wherein the array of LEDs are arranged in an electrical parallel relationship;

[0187] FIG. 53A is an alternate arrangement of the array of LEDs arranged in an electrical parallel relationship for the overall electrical circuit analogous to the overall electrical circuit shown in FIG. 53 for the alternate LED retrofit lamp;

[0188] FIG. 53B is another alternate arrangement of an array of LEDs arranged in an electrical series relationship for an overall electrical circuit analogous to the electrical circuit shown in FIG. 53 for the alternate LED retrofit lamp;

[0189] FIG. 53C is a simplified arrangement of the array of LEDs for the overall electrical circuit shown in FIG. 53 for the alternate LED retrofit lamp;

[0190] FIG. 53D is a simplified arrangement of the array of LEDs for the overall electrical circuit shown in FIG. 53A for the alternate LED retrofit lamp;

[0191] FIG. 53E is a simplified arrangement of the array of LEDs for the overall electrical circuit shown in FIG. 53B for the alternate LED retrofit lamp;

[0192] FIG. 53F shows a single high-brightness LED positioned on a single string in electrical series arrangement for the overall electrical circuit shown in FIG. 53 for the alternate retrofit lamp;

[0193] FIG. 53G shows two high-brightness LEDs in an electrical parallel arrangement of two parallel strings with one high-brightness LED positioned on each of the two parallel strings for the overall electrical circuit shown in FIG. 53 for the alternate retrofit lamp;

[0194] FIG. 54 is a schematic view showing the LED arrays in FIGS. 53 and 53A electrically connected to two opposed integral electronics circuitry that are electrically connected to base end caps each having a single-pin connection;

[0195] FIG. 55 is a schematic circuit of one of the two integral electronics circuitry shown in FIG. 54 positioned at one side of the alternating current voltage emanating from the ballast for the LED array shown in FIGS. 53 and 53A;

[0196] FIG. 56 is a schematic circuit of the other of the two integral electronics circuitry shown in FIG. 54 positioned at the other side of the alternating current voltage emanating from the ballast for the LED array shown in FIGS. 53 and 53A;

[0197] FIG. 57 is an isolated side view of the elongated cylindrical housing shown in FIGS. 50 and 51 detailing the cooling vent holes located at opposite ends;

[0198] FIG. 57A is an end view taken through line 57A-57A in FIG. 57;

[0199] FIG. 58 is a side view of an isolated single-pin end cap shown in FIGS. 50 and 54;

[0200] FIG. 58A is a sectional view taken through line 58A-58A of the end cap shown in FIG. 58;

[0201] FIG. 59 is an alternate sectional view to the sectional view of the alternate LED retrofit lamp taken through a single row of LEDs shown in FIG. 52;

[0202] FIG. 60 is a side view of the alternate retrofitted LED lamp mounted to an existing fluorescent fixture having an electronic rapid start, hybrid, or magnetic ballast having a pair of double contact electrical socket connectors;

[0203] FIG. 60A is a detailed end view of the alternate LED retrofit lamp taken through line 60A-60A of FIG. 60 showing a bi-pin electrical connector;

[0204] FIG. 61 is an exploded perspective view of the alternate LED retrofit lamp shown in FIG. 60 taken in isolation;

[0205] FIG. 62 is a cross-sectional view of the alternate LED retrofit lamp through a single row of LEDs taken through line 62-62 of FIG. 60;

[0206] FIG. 62A is a detailed mid-sectional cross-sectional view of a single LED of the LEDs shown in FIG. 62 with portions of the tubular wall and LED circuit board;

[0207] FIG. 63 is an overall electrical circuit for the alternate retrofitted LED lamp shown in FIG. 60 wherein the array of LEDs are arranged in an electrical parallel relationship;

[0208] FIG. 63A is an alternate arrangement of the array of LEDs arranged in an electrically parallel relationship for the overall electrical circuit shown in FIG. 63 for the alternate LED retrofit lamp;

[0209] FIG. 63B is another alternate arrangement of the array of LEDs arranged in an electrically parallel relationship for an overall electrical circuit analogous to the overall electrical circuit shown in FIG. 63 for the alternate LED retrofit lamp;

[0210] FIG. 63C is a simplified arrangement of the array of LEDs for the overall electrical circuit shown in FIG. 63 for the alternate LED retrofit lamp;

[0211] FIG. 63D is a simplified arrangement of the array of LEDs for the overall electrical circuit shown in FIG. 63A for the alternate LED retrofit lamp;

[0212] FIG. 63E is a simplified arrangement of the array of LEDs for the overall electrical circuit shown in FIG. 63B for the alternate LED retrofit lamp;

[0213] FIG. 63F shows a single high-brightness LED positioned on a single string in electrical series arrangement for the overall electrical circuit shown in FIG. 63 for the alternate retrofit lamp;

[0214] FIG. 63G shows two high-brightness LEDs in an electrical parallel arrangement of two parallel strings with one high-brightness LED positioned on each of the two parallel strings for the overall electrical circuit shown in FIG. 63 for the alternate retrofit lamp;

[0215] FIG. 64 is a schematic view showing the LED array in FIGS. 63 and 63A electrically connected to two opposed integral electronics circuitry that are electrically connected to base end caps each having a bi-pin connections;

[0216] FIG. 65 is a schematic circuit of one of the two integral electronics circuitry in FIG. 64 positioned at one side of the alternating current voltage emanating from the ballast for the LED array shown in FIGS. 63 and 63A;

[0217] FIG. 66 is a schematic circuit of the other of the two integral electronics circuitry shown in FIG. 64 positioned at the other side of the alternating current voltage emanating from the ballast for the LED array shown in FIGS. 63 and 63A;

[0218] FIG. 67 is an isolated side view of the elongated cylindrical housing shown in FIGS. 60 and 61 detailing the cooling vent holes located at opposite ends;

[0219] FIG. 67A is an end view taken through line 67A-67A in FIG. 67;

[0220] FIG. 68 is a side view of an isolated bi-pin end cap shown in FIGS. 60 and 64;

[0221] FIG. 68A is a sectional view taken through line 68A-68A of the end cap shown in FIG. 68;

[0222] FIG. 69 is an alternate sectional view to the sectional view of the alternate LED retrofit lamp taken through a single row of LEDs shown in FIG. 62;

[0223] FIG. 70 is a top view of an alternate LED retrofit lamp that is partly curved;

[0224] FIG. 71 is a sectional view of FIG. 70 taken through line 71-71;

[0225] FIG. 72 is a section view of an LED lamp 828A and 828B that is for mounting either to an instant start ballast assembly with opposed single pin contacts or to a rapid start ballast assembly with opposed bi-pin contacts;

[0226] FIG. 72A is an interior view of one circular single pin base end cap 830A taken in isolation representing both opposed base end caps of LED lamp 828A;

[0227] FIG. 72B is an interior view of one circular bi-pin base end cap 830B taken in isolation representing both opposed base end caps of LED lamp 828B;

[0228] FIG. 73 is a schematic block diagram showing an LED lamp including an AC power line from a ballast to a power converter and then to an LED array positioned in a tube with a switch on the DC power line also positioned therein and in operational power contact with an external manual control unit having three alternative data input signal lines to the switch;

[0229] FIG. 73A is a schematic block diagram showing an LED lamp including an AC power line from a ballast to a power converter and then to an LED array positioned in a tube with a computer and a dimmer on the DC power line also positioned therein and in operational power contact with an external manual control unit having three alternative data input signal lines to the computer;

[0230] FIG. 74 is a schematic block diagram showing an LED lamp including an AC power line from a ballast to a power converter and then to an LED array positioned in a tube with a timer and a switch on the DC power line also positioned therein and in operational contact with an external manual timer control unit having three alternative data input signal lines to the timer;

[0231] FIG. 74A is a schematic block diagram showing an LED lamp including an AC power line from a ballast to a power converter and then to an LED array positioned in a tube with a computer and a dimmer on the DC power line also positioned therein and in operational contact with an external manually operated timer and switch having three alternative data input signal lines to the computer;

[0232] FIG. 74B is a schematic block diagram showing an LED lamp including an AC power line from a ballast to a power converter and then to an LED array positioned in a tube with a timer, a switch, a computer, and a dimmer also positioned therein;

[0233] FIG. 75 is a schematic block diagram showing an LED lamp including an AC power line from a ballast to a power converter and then to an LED array positioned in a tube with a sensor in operational contact with a switch on the DC power line also positioned therein;

[0234] FIG. 75A is a schematic block diagram showing an LED lamp including an AC power line from a ballast to a power converter and then to an LED array positioned in a tube with a computer in operational communication with a sensor and a dimmer on the DC power line also positioned therein;

[0235] FIG. 75B is a schematic block diagram showing an LED lamp including an AC power line from a ballast to a power converter and then to an LED array positioned in a tube and a switch also positioned in the tube on the DC power line and in operational contact with a sensor positioned external to the tube having three alternative signal lines to the switch;

[0236] FIG. 75C is a schematic block diagram showing an LED lamp including an AC power line from a ballast to a power converter and then to an LED array positioned in a tube with a computer and a dimmer on the DC power line also positioned therein and a sensor positioned external to the tube having three alternative signal lines to the computer;

[0237] FIG. 76 is a schematic block diagram showing two LED lamps in network communication each including an AC power line from a ballast to a power converter and then to an LED array positioned in a tube with a sensor and a dimmer on the DC power line also positioned therein, and a computer in operational communication with both sensors and dimmers each using two alternative signal lines to and from the computer respectively;

[0238] FIG. 76A is a logic diagram related to the schematic block diagram shown in FIG. 76 that sets forth the four operational possibilities between the two LED lamps;

[0239] FIG. 77 is a schematic block diagram showing two LED lamps in network communication each including an AC power line from a ballast to a power converter and then to an LED array positioned in a tube with a sensor and operational contact with a sensor, a timer, and a dimmer also positioned therein in each LED lamp, and both computers being in operational signal communications with each other using two alternative signal lines;

[0240] FIG. 78 is a schematic block diagram showing two LED lamps in network communication each including an AC power line from a ballast to a power converter and then to an LED array positioned in a tube with a sensor and switch on the DC power line and in operational contact also positioned therein, and logic arrays in operational communication with the both sensors and switches each using two alternative signal lines to and from the logic arrays respectively;

[0241] FIG. 78A is a schematic block diagram showing two LED lamps in network communication each including an AC power line from a ballast to a power converter and then to an LED array positioned in a tube with logic arrays in operational contact with a sensor, a timer, and a switch also positioned therein in each LED lamp, and both sets of logic arrays being in operational signal communications with each other using two alternative signal lines;

[0242] FIG. 79A is an electrical circuit for providing DC power from a ballast to an LED array incorporating a voltage suppressor and a bridge rectifier on the power input side; and

[0243] FIG. 79B is an alternative electrical circuit analogous to FIG. 79A for providing DC power from a ballast to an LED array positioned in a tube incorporating a non-polarized capacitor, a zener diode, a varistor, and a bridge rectifier on the power input side. An optional filter capacitor is also shown.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0244] Reference is now made to the drawings and in particular to FIGS. 1-10 in which identical or similar parts are designated by the same reference numerals throughout.

[0245] An LED lamp 10 shown in FIGS. 1-10 is seen in FIG. 1 retrofitted to an existing elongated fluorescent fixture 12 mounted to a ceiling 14. An instant start type ballast assembly 16 is positioned within the upper portion of fixture 12. Fixture 12 further includes a pair of fixture mounting portions 18A and 18B extending downwardly from the ends of fixture 12 that include ballast electrical contacts shown as ballast end sockets 20A and 20B that are in electrical contact with ballast assembly 16. Fixture sockets 20A and 20B are each single contact sockets in accordance with the electrical operational requirement of an instant start type ballast. As also seen in FIG. 1A, LED lamp 10 includes opposed single-pin electrical contacts 22A and 22B that are positioned in ballast sockets 20A and 20B, respectively, so that LED lamp 10 is in electrical contact with ballast assembly 16.

[0246] As shown in the disassembled mode of FIG. 2 and also indicated schematically in FIG. 4, LED lamp 10

includes an elongated housing 24 particularly configured as a tubular wall 26 circular in cross-section taken transverse to a center line 28 that is made of a translucent material such as plastic or glass and preferably having a diffused coating. Tubular wall 26 has opposed tubular wall ends 30A and 30B. LED lamp 10 further includes a pair of opposed lamp base end caps 32A and 32B mounted to single electrical contact pins 22A and 22B, respectively for insertion in ballast electrical socket contacts 20A and 20B in electrical power connection to ballast assembly 16 so as to provide power to LED lamp 10. Tubular wall 26 is mounted to opposed base end caps 32A and 32B at tubular wall ends 30A and 30B in the assembled mode as shown in FIG. 1. LED lamp 10 also includes an electrical LED array circuit board 34 that is cylindrical in configuration. Although this embodiment describes a generally cylindrical configuration, it can be appreciated by someone skilled in the art to form the flexible circuit board 34 into shapes other than a cylinder for example, such as an elongated oval, triangle, rectangle, hexagon, octagon, etc. Accordingly, the shape of the tubular housing 24 holding the individual flexible circuit board 34 can be made in a similar shape to match the shape of the formed flexible circuit board 34 configuration. LED array circuit board 34 is positioned and held within tubular wall 26. In particular, LED array circuit board 34 has opposed circuit board circular ends 36A and 36B that are slightly inwardly positioned from tubular wall ends 30A and 30B, respectively. LED array circuit board 34 has interior and exterior cylindrical sides 38A and 38B, respectively with interior side 38A forming an elongated central passage 37 between tubular wall circular ends 30A and 30B and with exterior side 38B being spaced from tubular wall 26. LED array circuit board 34 is preferably assembled from a material that has a flat preassembled unbiased mode and an assembled self-biased mode as shown in the mounted position in FIGS. 2 and 3 wherein cylindrical sides 38A and 38B press outwardly towards tubular wall 26. LED array circuit board 34 is shown in FIG. 2 and indicated schematically in FIG. 5. LED lamp 10 further includes an LED array 40 comprising one hundred and fifty LEDs mounted to LED array circuit board 34. An integral electronics circuit board 42A is positioned between LED array circuit board 34 and base end cap 32A, and an integral electronics circuit board 42B is positioned between LED array circuit board 34 and base end cap 32B.

[0247] As seen in FIGS. 2 and 5, LED lamp 10 also includes a 6-pin connector 43A connected to integral electronics circuit board 42A, and a 6-pin header 44A positioned between and connected to 6-pin connector 43A and LED array circuit board 34. LED lamp 10 also includes a 6-pin connector 43B positioned for connection to 6-pin header 44A and LED array circuit board 34. Also, a 6-pin connector 43C is positioned for connection to LED array circuit board 34 and to a 6-pin header 44B, which is positioned for connection to a 6-pin connector 43D, which is connected to integral electronics circuit board 42B.

[0248] LED lamp 10 also includes an optional elongated cylindrical support member 46 defining a central passage 47 that is positioned within elongated housing 24 positioned immediately adjacent to and radially inward relative to and in support of cylindrical LED array electrical LED array circuit board 34. Cylindrical support member 46 is also shown in isolation in FIGS. 8 and 8A. Optional support member 46 is made of an electrically non-conductive mate-

rial such as rubber or plastic and is rigid in its position. It is preferably made of a self-biasable material and is in a biased mode in the cylindrical position, so that it presses radially outward in support of cylindrical LED array electrical LED array circuit board 34. Optional support member 46 is longitudinally aligned with tubular center line 28 of tubular member 26. Optional support member 46 further isolates integral electronics circuit boards 42A and 42B from LED array circuit board 34 containing the compact LED array 40. Optional support member 46, which is preferably made of a heat conducting material, may operate as a heat sink to draw heat away from LED array circuit board 34 and LED array 40 to the center of elongated housing 24 and thereby dissipating the heat out at the two ends 30A and 30B of tubular wall 26. Optional support member 46 defines cooling holes or holes 48 to allow heat from LED array 40 to flow to the center area of tubular wall 26 and from there to be dissipated at tubular circular ends 30A and 30B.

[0249] The sectional view of FIG. 3 taken through a typical single LED row 50 comprising ten individual LEDs 52 of the fifteen rows of LED array 40 shown in FIG. 4. LED row 50 is circular in configuration, which is representative of each of the fifteen rows of LED array 40 as shown in FIG. 4. Each LED 52 includes a light emitting lens portion 54, a body portion 56, and a base portion 58. A cylindrical space 60 is defined between interior side 38A of LED array circuit board 34 and cylindrical tubular wall 26. Each LED 52 is positioned in space 60 as seen in the detailed view of FIG. 3A, which is devoid of optional linear housing 24. Lens portion 54 is in juxtaposition with the inner surface of tubular wall 26 and base portion 58 is mounted to the outer surface of LED array circuit board 34 in electrical contact therewith. A detailed view of a single LED 52 shows a rigid LED electrical lead 62 extending from LED base portion 58 to LED array circuit board 34 for electrical connection therewith. Lead 62 is secured to LED circuit board 34 by solder 64. An LED center line 66 is aligned transverse to center line 28 of tubular wall 26. As shown in the sectional view of FIG. 3, light is emitted through tubular wall 26 by the ten LEDs 52 in equal strength about the entire circumference of tubular wall 26. Projection of this arrangement is such that all fifteen LED rows 50 are likewise arranged to emit light rays in equal strength the entire length of tubular wall 26 in equal strength about the entire 360-degree circumference of tubular wall 26. The distance between LED center line 66 and LED array circuit board 34 is the shortest that is geometrically possible. In FIG. 3A, LED center line 66 is perpendicular to tubular wall center line 28. FIG. 3A indicates a tangential plane 67 relative to the cylindrical inner surface of linear wall 26 in phantom line at the apex of LED lens portion 54 that is perpendicular to LED center line 66 so that all LEDs 52 emit light through tubular wall 26 in a direction perpendicular to tangential line 67 so that maximum illumination is obtained from all LEDs 52.

[0250] FIG. 4 shows the total LED electrical circuitry for LED lamp 10. The total LED circuitry is shown in a schematic format that is flat for purposes of exposition. The total LED circuitry comprises two circuit assemblies, namely, existing ballast assembly circuitry 68 and LED circuitry 70, the latter including LED array circuitry 72, and integral electronics circuitry 84. LED circuitry 70 provides electrical circuits for LED lighting element array 40. When electrical power, normally 120 VAC or 240 VAC at 50 or 60

Hz, is applied, ballast circuitry 68 as is known in the art of instant start ballasts provides either an AC or DC voltage with a fixed current limit across ballast socket electrical contacts 20A and 20B, which is conducted through LED circuitry 70 by way of single contact pins 22A and 22B to a voltage input at a bridge rectifier 74. Bridge rectifier 74 converts AC voltage to DC voltage if ballast circuitry 68 supplies AC voltage. In such a situation wherein ballast circuitry 68 supplies DC voltage, the voltage remains DC voltage even in the presence of bridge rectifier 74.

[0251] LEDs 52 have an LED voltage design capacity, and a voltage suppressor 76 is used to protect LED lighting element array 40 and other electronic components primarily including LEDs 52 by limiting the initial high voltage generated by ballast circuitry 68 to a safe and workable voltage.

[0252] Bridge rectifier 74 provides a positive voltage V+ to an optional resettable fuse 78 connected to the anode end and also provides current protection to LED array circuitry 72. Fuse 78 is normally closed and will open and de-energize LED array circuitry 72 only if the current exceeds the allowable current through LED array 40. The value for resettable fuse 78 should be equal to or be lower than the maximum current limit of ballast assembly 16. Fuse 78 will reset automatically after a cool-down period.

[0253] Ballast circuitry 68 limits the current going into LED circuitry 70. This limitation is ideal for the use of LEDs in general and of LED lamp 10 in particular because LEDs are basically current devices regardless of the driving voltage. The actual number of LEDs will vary in accordance with the actual ballast assembly 16 used. In the example of the embodiment herein, ballast assembly 16 provides a maximum current limit of 300 mA.

[0254] LED array circuitry 72 includes fifteen electrical strings 80 individually designated as strings 80A, 80B, 80C, 80D, 80E, 80F, 80G, 80H, 80I, 80J, 80K, 80L, 80M, 80N and 80O all in parallel relationship with all LEDs 52 within each string 80A-80O being electrically wired in series. Parallel strings 80 are so positioned and arranged that each of the fifteen strings 80 is equidistant from one another. LED array circuitry 72 includes ten LEDs 52 electrically mounted in series within each of the fifteen parallel strings 80A-O for a total of one-hundred and fifty LEDs 52 that constitute LED array 40. LEDs 52 are positioned in equidistant relationship with one another and extend generally the length of tubular wall 26, that is, generally between tubular wall ends 30A and 30B. As shown in FIG. 4, each of strings 80A-80O includes an optional resistor 82 designated individually as resistors 82A, 82B, 82C, 82D, 82E, 82F, 82G, 82H, 82I, 82J, 82K, 82L, 82M, 82N, and 82O in respective series alignment with strings 80A-80O at the current input for a total of fifteen resistors 82. The current limiting resistors 82A-82O are purely optional, because the existing fluorescent ballast used here is already a current limiting device. The resistors 82A-82O then serve as secondary protection devices. A higher number of individual LEDs 52 can be connected in series within each LED string 80. The maximum number of LEDs 52 being configured around the circumference of the 1.5-inch diameter of tubular wall 26 in the particular example herein of LED lamp 10 is ten. Each LED 52 is configured with the anode towards the positive voltage V+ and the cathode towards the negative voltage V-. When

LED array circuitry 72 is energized, the positive voltage that is applied through resistors 82A-82O to the anode end of circuit strings 80A-80O and the negative voltage that is applied to the cathode end of circuit strings 80A-80O will forward bias LEDs 52 connected to strings 80A-80O and cause LEDs 52 to turn on and emit light.

[0255] Ballast assembly 16 regulates the electrical current through LEDs 52 to the correct value of 20 mA for each LED 52. The fifteen LED strings 80 equally divide the total current applied to LED array circuitry 72. Those skilled in the art will appreciate that different ballasts provide different current outputs.

[0256] If the forward drive current for LEDs 52 is known, then the output current of ballast assembly 16 divided by the forward drive current gives the exact number of parallel strings of LEDs 52 in the particular LED array, here LED array 40. The total number of LEDs in series within each LED string 80 is arbitrary since each LED 52 in each LED string 80 will see the same current. Again in this example, ten LEDs 52 are shown connected in series within each LED string 80 because of the fact that only ten LEDs 52 of the 5 mm discrete type of LED will fit around the circumference of a 1.5-inch diameter lamp housing. Ballast assembly 16 provides 300 mA of current, which when divided by the fifteen LED strings 80 of ten LEDs 52 per LED string 80 gives 20 mA per LED string 80. Each of the ten LEDs 52 connected in series within each LED string 80 sees this 20 mA. In accordance with the type of ballast assembly 16 used, when ballast assembly 16 is first energized, a high voltage may be applied momentarily across ballast socket contacts 20A and 20B, which conduct to pin contacts 22A and 22B. Such high voltage is normally used to help ignite a fluorescent tube and establish conductive phosphor gas, but high voltage is unnecessary for LED array circuitry 72 and voltage surge absorber 76 absorbs the voltage applied by ballast circuitry 68, so that the initial high voltage supplied is limited to an acceptable level for the circuit. Optional resettable fuse 78 is also shown to provide current protection to LED array circuitry 72.

[0257] As can be seen from FIG. 4A, there can be more than ten LEDs 52 connected in series within each string 80A-80O. There are twenty LEDs 52 in this example, but there can be more LEDs 52 connected in series within each string 80A-80O. The first ten LEDs 52 of each parallel string will fill the first 1.5-inch diameter of the circumference of tubular wall 26, the second ten LEDs 52 of the same parallel string will fill the next adjacent 1.5-inch diameter of the circumference of tubular wall 26, and so on until the entire length of the tubular wall 26 is substantially filled with all LEDs 52 comprising the total LED array 40.

[0258] LED array circuitry 72 includes fifteen electrical LED strings 80 individually designated as strings 80A, 80B, 80C, 80D, 80E, 80F, 80G, 80H, 80I, 80J, 80K, 80L, 80M, 80N and 80O all in parallel relationship with all LEDs 52 within each string 80A-80O being electrically wired in series. Parallel strings 80 are so positioned and arranged that each of the fifteen strings 80 is equidistant from one another. LED array circuitry 72 includes twenty LEDs 52 electrically mounted in series within each of the fifteen parallel strings 80A-O for a total of three-hundred LEDs 52 that constitute LED array 40. LEDs 52 are positioned in equidistant relationship with one another and extend generally the length of

tubular wall 26, that is, generally between tubular wall ends 30A and 30B. As shown in FIGS. 4 and 4A, each of strings 80A-80O includes an optional resistor 82 designated individually as resistors 82A, 82B, 82C, 82D, 82E, 82F, 82G, 82H, 82I, 82J, 82K, 82L, 82M, 82N, and 82O in respective series alignment with strings 80A-80O at the current input for a total of fifteen resistors 82. Again, a higher number of individual LEDs 52 can be connected in series within each LED string 80. The maximum number of LEDs 52 being configured around the circumference of the 1.5-inch diameter of tubular wall 26 in the particular example herein of LED lamp 10 is ten. Each LED 52 is configured with the anode towards the positive voltage V+ and the cathode towards the negative voltage V-. When LED array circuitry 72 is energized, the positive voltage that is applied through resistors 82A-82O to the anode end of circuit strings 80A-80O and the negative voltage that is applied to the cathode end of circuit strings 80A-80O will forward bias LEDs 52 connected to strings 80A-80O and cause LEDs 52 to turn on and emit light.

[0259] Ballast assembly 16 regulates the electrical current through LEDs 52 to the correct value of 20 mA for each LED 52. The fifteen LED strings 80 equally divide the total current applied to LED array circuitry 72. Those skilled in the art will appreciate that different ballasts provide different current outputs.

[0260] If the forward drive current for LEDs 52 is known, then the output current of ballast assembly 16 divided by the forward drive current gives the exact number of parallel strings of LEDs 52 in the particular LED array, here LED array 40. The total number of LEDs in series within each LED string 80 is arbitrary since each LED 52 in each LED string 80 will see the same current. Again in this example, twenty LEDs 52 are shown connected in series within each LED string 80 because of the fact that only ten LEDs 52 of the 5 mm discrete type of LED will fit around the circumference of a 1.5-inch diameter lamp housing. Ballast assembly 16 provides 300 mA of current, which when divided by the fifteen strings 80 of ten LEDs 52 per LED string 80 gives 20 mA per LED string 80. Each of the twenty LEDs 52 connected in series within each LED string 80 sees this 20 mA. In accordance with the type of ballast assembly 16 used, when ballast assembly 16 is first energized, a high voltage may be applied momentarily across ballast socket contacts 20A and 20B, which conduct to pin contacts 22A and 22B. Such high voltage is normally used to help ignite a fluorescent tube and establish conductive phosphor gas, but high voltage is unnecessary for LED array circuitry 72 and voltage surge absorber 76 absorbs the voltage applied by ballast circuitry 68, so that the initial high voltage supplied is limited to an acceptable level for the circuit.

[0261] FIG. 4B shows another alternate arrangement of LED array circuitry 72. LED array circuitry 72 consists of a single LED string 80 of LEDs 52 arranged in series relationship including for exposition purposes only forty LEDs 52 all electrically connected in series. Positive voltage V+ is connected to optional resettable fuse 78, which in turn is connected to one side of current limiting resistor 82. The anode of the first LED in the series string is then connected to the other end of resistor 82. A number other than forty LEDs 52 can be connected within the series LED string 80 to fill up the entire length of the tubular wall of the present invention. The cathode of the first LED 52 in the series LED

string **80** is connected to the anode of the second LED **52**; the cathode of the second LED **52** in the series LED string **80** is then connected to the anode of the third LED **52**, and so forth. The cathode of the last LED **52** in the series LED string **80** is likewise connected to ground or the negative potential V^- . The individual LEDs **52** in the single series LED string **80** are so positioned and arranged such that each of the forty LEDs is spaced equidistant from one another substantially filling the entire length of tubular wall **26**. LEDs **52** are positioned in equidistant relationship with one another and extend substantially the length of tubular wall **26**, that is, generally between tubular wall ends **30A** and **30B**. As shown in **FIG. 4B**, the single series LED string **80** includes an optional resistor **82** in respective series alignment with single series LED string **80** at the current input. Each LED **52** is configured with the anode towards the positive voltage V^+ and the cathode towards the negative voltage V^- . When LED array circuitry **72** is energized, the positive voltage that is applied through resistor **82** to the anode end of single series LED string **80** and the negative voltage that is applied to the cathode end of single series LED string **80** will forward bias LEDs **52** connected in series within single series LED string **80**, and cause LEDs **52** to turn on and emit light.

[0262] The single series LED string **80** of LEDs **52** as described above works ideally with the high-brightness or brighter high flux white LEDs available from Lumileds and Nichia in the SMD (surface mounted device) packages as discussed earlier herein. Since these new devices require more current to drive them and run on low voltages, the high current available from existing fluorescent ballast outputs with current outputs of 300 mA and higher, along with their characteristically higher voltage outputs provide the perfect match for the present invention. The high-brightness LEDs **52A** have to be connected in series, so that each high-brightness LED **52A** within the same single LED string **80** will see the same current and therefore output the same brightness. The total voltage required by all the high-brightness LEDs **52A** within the same single LED string **80** is equal to the sum of all the individual voltage drops across each high-brightness LED **52A** and should be less than the maximum voltage output of ballast assembly **16**.

[0263] **FIG. 4C** shows a simplified arrangement of the LED array circuitry **72** of LEDs **52** shown for purposes of exposition in a flat compressed position for the overall electrical circuit shown in **FIG. 4**. AC lead lines **86** and **90** and DC positive lead line **92** and DC negative lead line **94** are connected to integral electronics circuit boards **42A** and **42B** by way of 6-pin headers **44A** and **44B** and connectors **43A-43D**. Four parallel LED strings **80** each including a resistor **82** are each connected to DC positive lead line **92** on one side, and to LED positive lead line **100** or the anode side of each LED **52** and on the other side. The cathode side of each LED **52** is then connected to LED negative lead line **102** and to DC negative lead line **94** directly. AC lead lines **86** and **90** simply pass through LED array circuitry **72**.

[0264] **FIG. 4D** shows a simplified arrangement of the LED array circuitry **72** of LEDs **52** shown for purposes of exposition in a flat compressed position for the overall electrical circuit shown in **FIG. 4A**. AC lead lines **86** and **90** and DC positive lead line **92** and DC negative lead line **94** are connected to integral electronics boards **42A** and **42B** by way of 6-pin headers **44A** and **44B** and connectors **43A-**

43D. Two parallel LED strings **80** each including a single resistor **82** are each connected to DC positive lead line **92** on one side, and to LED positive lead line **100** or the anode side of the first LED **52** in each LED string **80** on the other side. The cathode side of the first LED **52** is connected to LED negative lead line **102** and to adjacent LED positive lead line **100** or the anode side of the second LED **52** in the same LED string **80**. The cathode side of the second LED **52** is then connected to LED negative lead line **102** and to DC negative lead line **94** directly in the same LED string **80**. AC lead lines **86** and **90** simply pass through LED array circuitry **72**.

[0265] **FIG. 4E** shows a simplified arrangement of the LED array circuitry **72** of LEDs **52** shown for purposes of exposition in a flat compressed position for the overall electrical circuit shown in **FIG. 4B**. AC lead lines **86** and **90** and DC positive lead line **92** and DC negative lead line **94** are connected to integral electronics boards **42A** and **42B** by way of 6-pin headers **44A** and **44B** and connectors **43A-43D**. Single parallel LED string **80** including a single resistor **82** is connected to DC positive lead line **92** on one side, and to LED positive lead line **100** or the anode side of the first LED **52** in the LED string **80** on the other side. The cathode side of the first LED **52** is connected to LED negative lead line **102** and to adjacent LED positive lead line **100** or the anode side of the second LED **52**. The cathode side of the second LED **52** is connected to LED negative lead line **102** and to adjacent LED positive lead line **100** or the anode side of the third LED **52**. The cathode side of the third LED **52** is connected to LED negative lead line **102** and to adjacent LED positive lead line **100** or the anode side of the fourth LED **52**. The cathode side of the fourth LED **52** is then connected to LED negative lead line **102** and to DC negative lead line **94** directly. AC lead lines **86** and **90** simply pass through LED array circuitry **72**.

[0266] The term high-brightness as describing LEDs herein is a relative term. In general, for the purposes of the present application, high-brightness LEDs refer to LEDs that offer the highest luminous flux outputs. Luminous flux is defined as lumens per watt. For example, Lumileds Luxeon high-brightness LEDs produce the highest luminous flux outputs at the present time. Luxeon 5-watt high-brightness LEDs offer extreme luminous density with lumens per package that is four times the output of an earlier Luxeon 1-watt LED and up to 50 times the output of earlier discrete 5 mm LED packages. Gelcore is soon to offer an equivalent and competitive product.

[0267] With the new high-brightness LEDs in mind, **FIG. 4F** shows a single high-brightness LED **52A** positioned on an electrical string in what is defined herein as an electrical series arrangement with single a high-brightness LED **52A** for the overall electrical circuit shown in **FIG. 4**. The single high-brightness LED **52A** fulfills a particular lighting requirement formerly fulfilled by a fluorescent lamp.

[0268] Likewise, **FIG. 4G** shows two high-brightness LEDs **52A** in electrical parallel arrangement with one high-brightness LED **52A** positioned on each of the two parallel strings for the overall electrical circuit shown in **FIG. 4**. The two high-brightness LEDs **52A** fulfill a particular lighting requirement formerly fulfilled by a fluorescent lamp.

[0269] The single LED string **80** of SMD LEDs **52** connected in series can be mounted onto a long thin strip flexible circuit board made of polyimide or equivalent

material. The flexible circuit board **34** is then spirally wrapped into a generally cylindrical configuration. Although this embodiment describes a generally cylindrical configuration, it can be appreciated by someone skilled in the art to form the flexible circuit board **34** into shapes other than a cylinder, such as an elongated oval, triangle, rectangle, hexagon, and octagon, as some examples of a wide possible variation of configurations. Accordingly, the shape of the tubular housing **24** holding the single wrapped flexible circuit board **34** can be made in a similar shape to match the shape of the formed flexible circuit board **34** configuration.

[0270] LED array circuit board **34** is positioned and held within tubular wall **26**. As in **FIGS. 2 and 5**, LED array circuit board **34** has opposed circuit board circular ends **36A** and **36B** that are slightly inwardly positioned from tubular wall ends **30A** and **30B**, respectively. LED array circuit board **34** has interior and exterior cylindrical sides **38A** and **38B**, respectively with interior side **38A** forming an elongated central passage **37** between tubular wall circular ends **30A** and **30B** with exterior side **38B** being spaced from tubular wall **26**. LED array circuit board **34** is preferably assembled from a material that has a flat preassembled unbiased mode and an assembled self-biased mode wherein cylindrical sides **38A** and **38B** press outwardly towards tubular wall **26**. The SMD LEDs **52** are mounted on exterior cylindrical side **38B** with the lens **54** of each LED **52** held in juxtaposition with tubular wall **25** and pointing radially outward from center line **28**. As shown in the sectional view of **FIG. 3**, light is emitted through tubular wall **26** by LEDs **52** in equal strength about the entire 360-degree circumference of tubular wall **26**.

[0271] As described earlier in **FIGS. 2 and 5**, an optional support member **46** is made of an electrically non-conductive material such as rubber or plastic and is held rigid in its position. It is preferably made of a self-biasable material and is in a biased mode in the cylindrical position, so that it presses radially outward in holding support of cylindrical LED array electrical LED array circuit board **34**. Optional support member **46** is longitudinally aligned with tubular center line **28** of tubular member **26**. Optional support member **46** further isolates integral electronics circuit boards **42A** and **42B** from LED array circuit board **34** containing the compact LED array **40**. Optional support member **46**, which is preferably made of a heat conducting material, may operate as a heat sink to draw heat away from LED array circuit board **34** and LED array **40** to the center of elongated housing **24** and thereby dissipating the heat out at the two ends **30A** and **30B** of tubular wall **26**. Optional support member **46** defines cooling holes or holes **48** to allow heat from LED array **40** to flow to the center area of tubular wall **26** and from there to be dissipated at tubular circular ends **30A** and **30B**.

[0272] Ballast assembly **16** regulates the electrical current through LEDs **52** to the correct value of 300 mA or other ballast assembly **16** rated lamp current output for each LED **52**. The total current is applied to both the single LED string **80** and to LED array circuitry **72**. Again, those skilled in the art will appreciate that different ballasts provide different rated lamp current outputs.

[0273] If the forward drive current for LEDs **52** is known, then the output current of ballast assembly **16** divided by the forward drive current gives the exact number of parallel

strings **80** of LEDs **52** in the particular LED array, here LED array **40** shown in electrically parallel configuration in **FIG. 4** and in electrically series configurations in **FIGS. 4A and 4B**. Since the forward drive current for LEDs **52** is equal to the output current of ballast assembly **16**, then the result is a single series LED string **80** of LEDs **52**. The total number of LEDs in series within each series LED string **80** is arbitrary since each LED **52** in each series LED string **80** will see the same current. Again in this example shown in **FIG. 4B**, forty LEDs **52** are shown connected within series LED string **80**. Ballast assembly **16** provides 300 mA of current, which when divided by the single series LED string **80** of forty LEDs **52** gives 300 mA for single series LED string **80**. Each of the forty LEDs **52** connected in series within single series LED string **80** sees this 300 mA. In accordance with the type of ballast assembly **16** used, when ballast assembly **16** is first energized, a high voltage may be applied momentarily across ballast socket contacts **20A** and **20B**, which conduct to pin contacts **22A** and **22B**. Such high voltage is normally used to help ignite a fluorescent tube and establish conductive phosphor gas, but high voltage is unnecessary for LED array circuitry **72** and voltage surge absorber **76** absorbs the voltage applied by ballast circuitry **68**, so that the initial high voltage supplied is limited to an acceptable level for the circuit.

[0274] It can be seen from someone skilled in the art from **FIGS. 4, 4A, and 4B** that the LED array **40** can consist of at least one parallel electrical LED string **80** containing at least one LED **52** connected in series within each parallel electrical LED string **80**. Therefore, the LED array **40** can consist of any number of parallel electrical strings **80** combined with any number of LEDs **52** connected in series within electrical strings **80**, or any combination thereof.

[0275] **FIGS. 4C, 4D, and 4E** show simplified electrical arrangements of the array **40** of LEDs **52** shown with at least one LED **52** in a series parallel configuration. Each LED string **80** has an optional resistor **82** in series with each LED **52**.

[0276] As shown in the schematic electrical and structural representations of **FIG. 5**, LED array circuit board **34** of LED array **40** is positioned between integral electronics circuit board **42A** and **42B** that in turn are electrically connected to ballast circuitry **68** by single contact pins **22A** and **22B**, respectively. Single contact pins **22A** and **22B** are mounted to and protrude out from base end caps **32A** and **32B**, respectively, for electrical connection to integral electronics circuit boards **42A** and **42B**. Contact pins **22A** and **22B** are soldered directly to integral electronics circuit boards **42A** and **42B**, respectively. In particular, pin inner extension **22D** of connecting pin **22A** is electrically connected by being soldered directly to the integral electronics circuit board **42A**. Similarly, being soldered directly to integral electronics circuit board **42B** electrically connects pin inner extension **22F** of connecting pin **22B**. 6-pin connector **44A** is shown positioned between and in electrical connection with integral electronics circuit board **42A** and LED array circuit board **34** and LED circuitry **70** shown in **FIG. 4** mounted thereon. 6-pin connector **44B** is shown positioned between and in electrical connection with integral electronics circuit board **42B** and LED array circuit board **34** and LED circuitry **70** mounted thereon.

[0277] As seen in **FIG. 6**, a schematic of integral electronics circuitry **84** is mounted on integral electronics circuit

board 42A. Integral electronics circuit 84 is also shown in FIG. 4 as part of the schematically shown LED circuitry 70. Integral electronics circuitry 84 is in electrical contact with ballast socket contact 20A, which is shown as providing AC voltage. Integral electronics circuitry 84 includes bridge rectifier 74, voltage surge absorber 76, and fuse 78. Bridge rectifier 74 converts AC voltage to DC voltage. Voltage surge absorber 76 limits the high voltage to a workable voltage within the design voltage capacity of LEDs 52. The DC voltage circuits indicated as plus (+) and minus (−) and indicated as DC leads 92 and 94 lead to and from LED array 40 (not shown). It is noted that FIG. 6 indicates the presence of AC voltage by an AC wave symbol ~. Each AC voltage could be DC voltage supplied by certain ballast assemblies 16 as mentioned earlier herein. In such a case DC voltage would be supplied to LED lighting element array 40 even in the presence of bridge rectifier 74. It is particularly noted that in such a case, voltage surge absorber 76 would remain operative.

[0278] FIG. 7 shows a further schematic of integral electronics circuit 42B that includes integral electronics circuitry 88 mounted on integral electronics board 42B with voltage protected AC lead line 90 extending from LED array 40 (not shown) and by extension from integral electronics circuitry 84. The AC lead line 90 having passed through voltage surge absorber 76 is a voltage protected circuit and is in electrical contact with ballast socket contact 20B. Integral circuitry 88 includes DC positive and DC negative lead lines 92 and 94, respectively, from LED array circuitry 72 to positive and negative DC terminals 96 and 98, respectively, mounted on integral electronics board 42B. Integral circuitry 88 further includes AC lead line 90 from LED array circuitry 72 to ballast socket contact 20B.

[0279] FIGS. 6 and 7 show the lead lines going into and out of LED circuitry 70 respectively. The lead lines include AC lead lines 86 and 90, positive DC voltage 92, DC negative voltage 94, LED positive lead line 100, and LED negative lead line 102. The AC lead lines 86 and 90 are basically feeding through LED circuitry 70, while the positive DC voltage lead line 92 and negative DC voltage lead line 94 are used primarily to power the LED array 40. DC positive lead line 92 is the same as LED positive lead line 100 and DC negative lead line 94 is the same as LED negative lead line 102. LED array circuitry 72 therefore consists of all electrical components and internal wiring and connections required to provide proper operating voltages and currents to LEDs 52 connected in parallel, series, or any combinations of the two.

[0280] FIGS. 8 and 8A show the optional support member 46 with cooling holes 48 in both side and cross-sectional views respectively.

[0281] FIG. 9 shows an isolated view of one of the base end caps, namely, base end cap 32A, which is the same as base end cap 32B, mutatis mutandis. Single-pin contact 22A extends directly through the center of base end cap 32A in the longitudinal direction in alignment with center line 28 of tubular wall 26 relative to tubular wall 26. Single-pin 22A as also shown in FIG. 1 where single-pin contact 22A is mounted into ballast socket contact 20A. Single-pin contact 22A also includes pin extension 22D that is outwardly positioned from base end cap 32A in the direction towards tubular wall 26. Base end cap 32A is a solid cylinder in

configuration as seen in FIGS. 9 and 9A and forms an outer cylindrical wall 104 that is concentric with center line 28 of tubular wall 26 and has opposed flat end walls 106A and 106B that are perpendicular to center line 28. Two cylindrical parallel vent holes 108A and 108B are defined between flat end walls 106A and 106B spaced directly above and below and lateral to single-pin contact 22A. Single-pin contact 22A includes external side pin extension 22C and internal side pin extension 22D that each extend outwardly positioned from opposed flat end walls 106A and 106B, respectively, for electrical connection with ballast socket contact 20A and with integral electronics board 42A. Analogous external and internal pin extensions for contact pin 22B likewise exist for electrical connections with ballast socket contact 20B and with integral electronics board 42B.

[0282] As also seen in FIG. 9A, base end cap 32A defines an outer circular slot 110 that is concentric with center line 28 of tubular wall 26 and concentric with and aligned proximate to circular wall 104. Circular slot 110 is spaced from cylindrical wall 104 at a convenient distance. Circular slot 110 is of such a width and circular end 30A of tubular wall 26 is of such a thickness that circular end 30A is fitted into circular slot 110 and is thus supported by circular slot 110. Base end cap 32B (not shown in detail) defines another circular slot (not shown) analogous to circular slot 110 that is likewise concentric with center line 28 of tubular wall 26 so that circular end 30B of tubular wall 26 can be fitted into the analogous circular slot of base end cap 32B wherein circular end 30B is also supported. In this manner tubular wall 26 is mounted to end caps 32A and 32B.

[0283] As also seen in FIG. 9A, base end cap 32A defines another inner circular slot 112 that is concentric with center line 28 of tubular wall 26 and concentric with and spaced radially inward from circular slot 110. Circular slot 112 is spaced from circular slot 110 at such a distance that would be occupied by LEDs 52 mounted to LED array circuit board 34 within tubular wall 26. Circular slot 112 is of such a width and circular end 36A of LED array circuit board 34 is of such a thickness that circular end 36A is fitted into circular slot 112 and is thus supported by circular slot 112. Base end cap 32B (not shown) defines another circular slot analogous to circular slot 112 that is likewise concentric with center line 28 of tubular wall 26 so that circular end 36B of LED array circuit board 34 can be fitted into the analogous circular slot of base end cap 32B wherein circular end 36B is also supported. In this manner LED array circuit board 34 is mounted to end caps 32A and 32B.

[0284] Circular ends 30A and 30B of tubular wall 26 and also circular ends 36A and 36B of LED array circuit board 34 are secured to base end caps 32A and 32B preferably by gluing in a manner known in the art. Other securing methods known in the art of attaching such as cross-pins or snaps can be used.

[0285] An analogous circular slot (not shown) concentric with center line 28 is optionally formed in flat end walls 106A and 106B of base end cap 32A and analogous circular slot in the flat end walls of base end cap 32B radially inward from LED circuit board circular slot 112 for insertion of the opposed ends of optional support member 46.

[0286] Circular ends 30A and 30B of tubular wall 26 are optionally press fitted to circular slot 110 of base end cap 32A and the analogous circular slot of base end cap 32B.

[0287] FIG. 10 is a sectional view of an alternate LED lamp 114 mounted to tubular wall 26 that is a version to LED lamp 10 as shown in FIG. 3. The sectional view of LED lamp 114 shows a single row 50A of the LEDs of LED lamp 114 and includes a total of six LEDs 52, with four LEDs 52X being positioned at equal intervals at the bottom area 116 of tubular wall 26 and with two LEDs 52Y positioned at opposed side areas 118 of tubular wall 26A. LED array circuitry 72 previously described with reference to LED lamp 10 would be the same for LED lamp 114. That is, all fifteen strings 80 of the LED array of LED lamp 10 would be the same for LED lamp 114, except that a total of ninety LEDs 52 would comprise LED lamp 114 with the ninety LEDs 52 positioned at strings 80 at such electrical connectors that would correspond with LEDs 52X and 52Y throughout. The reduction to ninety LEDs 52 of LED lamp 114 from the one hundred and fifty LEDs 52 of LED lamp 10 would result in a forty percent reduction of power demand with an illumination result that would be satisfactory under certain circumstances. Additional stiffening of LED array circuit board 34 for LED lamp 114 is accomplished by circular slot 112 for tubular wall 26 or optionally by the additional placement of LEDs 52 at the top vertical position in space 60 (not shown) or optionally a vertical stiffening member 122 shown in phantom line that is positioned at the upper area of space 60 between LED array circuit board 34 and the inner side of tubular wall 26 and extends the length of tubular wall 26 and LED array circuit board 34.

[0288] LED lamp 10 as described above will work for both AC and DC voltage outputs from an existing fluorescent ballast assembly 16. In summary, LED array 40 will ultimately be powered by DC voltage. If existing fluorescent ballast 16 operates with an AC output, bridge rectifier 74 converts the AC voltage to DC voltage. Likewise, if existing fluorescent ballast 16 operates with a DC voltage, the DC voltage remains a DC voltage even after passing through bridge rectifier 26.

[0289] Another embodiment of a retrofitted LED lamp is shown in FIGS. 11-20. FIG. 11 shows an LED lamp 124 retrofitted to an existing elongated fluorescent fixture 126 mounted to a ceiling 128. A rapid start type ballast assembly 130 including a starter 130A is positioned within the upper portion of fixture 126. Fixture 126 further includes a pair of fixture mounting portions 132A and 132B extending downwardly from the ends of fixture 126 that include ballast electrical contacts shown in FIG. 11A as ballast double contact sockets 134A and 136A and ballast opposed double contact sockets 134A and 136B that are in electrical contact with ballast assembly 130. Ballast double contact sockets 134A, 136A and 134B, 136B are each double contact sockets in accordance with the electrical operational requirement of a rapid start type ballast. As also seen in FIG. 11A, LED lamp 124 includes bi-pin electrical contacts 138A and 140A that are positioned in ballast double contact sockets 134A and 136A, respectively. LED lamp 124 likewise includes opposed bi-pin electrical contacts 138B and 140B that are positioned in ballast double contact sockets 134B and 136B, respectively. In this manner, LED lamp 124 is in electrical contact with ballast assembly 130.

[0290] As shown in the disassembled mode of FIG. 12 and also indicated schematically in FIG. 14, LED lamp 124 includes an elongated tubular housing 142 particularly con-

figured as a tubular wall 144 circular in cross-section taken transverse to a center line 146. Tubular wall 144 is made of a translucent material such as plastic or glass and preferably has a diffused coating. Tubular wall 144 has opposed tubular wall circular ends 148A and 148B. LED lamp 124 further includes a pair of opposed lamp base end caps 150A and 150B mounted to bi-pin electrical contacts 138A, 140A and 138B, 140B, respectively, for insertion in ballast electrical socket contacts 134A, 136A and 134B, 136B, respectively, in electrical power connection to ballast assembly 130 so as to provide power to LED lamp 124. Tubular wall 144 is mounted to opposed base end caps 150A and 150B at tubular wall circular ends 148A and 148B, respectively, in the assembled mode as shown in FIG. 11. LED lamp 124 also includes an LED array electrical circuit board 152 that is cylindrical in configuration and has opposed circuit board circular ends 154A and 154B.

[0291] It can be appreciated by someone skilled in the art to form the flexible circuit board 152 into shapes other than a cylinder, such as an elongated oval, triangle, rectangle, hexagon, octagon, among many possible configurations when the elongated tubular housing 142 has a like configuration. It can also be said that the shape of the tubular housing 142 holding the individual flexible circuit board 152 can be made in a similar shape to match the shape of the formed flexible circuit board 152 frame. Circuit board 152 is positioned and held within tubular wall 144. In particular, circuit board 152 has opposed circuit board ends 154A and 154B that are slightly inwardly positioned from tubular wall ends 148A and 148B, respectively. Circuit board 152 has opposed interior and exterior cylindrical sides 156A and 156B, respectively with exterior side 156B being spaced from tubular wall 144. Circuit board 152 is preferably assembled from a material that has a flat preassembled unbiased mode and an assembled self-biased mode as shown in the mounted position in FIGS. 12 and 13 wherein cylindrical sides 156A and 156B press outwardly towards tubular wall 144. Circuit board 152 is shown in FIG. 12 and indicated schematically in FIG. 14. LED lamp 124 further includes an LED array 158 comprising one hundred and fifty LEDs mounted to circuit board 152. An integral electronics circuit board 160A is positioned between circuit board 152 and base end cap 150A, and an integral electronics circuit board 160B is positioned between circuit board 152 and base end cap 150B.

[0292] As seen in FIGS. 12 and 15, LED lamp 124 also includes a 6-pin connector 161A connected to integral electronics circuit board 160A, and a 6-pin header 162A positioned between and connected to 6-pin connector 161A and circuit board 152. LED lamp 124 also includes a 6-pin connector 161B positioned for connection to 6-pin header 162A and circuit board 152. Also, a 6-pin connector 161C is positioned for connection to circuit board 152 and to a 6-pin header 162B, which is positioned for connection to a 6-pin connector 161D, which is connected to integral electronics circuit board 160B.

[0293] LED lamp 124 also includes an optional elongated cylindrical support member 164 that is positioned within elongated housing 142 positioned immediately adjacent to and radially inward relative to and in support of LED array electrical circuit board 152. Optional support member 164 is also shown in isolation in FIGS. 18 and 18A. Optional support member 164 is made of an electrically non-conduc-

tive material such as rubber or plastic and is rigid in its position. It is preferably made of a self-biasable material and is in a biased mode in the cylindrical position, so that it presses radially outward in support of cylindrical LED array electrical circuit board 152. Optional support member 164 is longitudinally and cylindrically aligned with tubular center line 146 of tubular wall 144. Optional support member 164 further isolates integral electronics circuit boards 160A and 160B from LED array circuit board 152 containing the circuitry for LED array 158. Optional support member 164, which may be made of a heat conducting material, can operate as a heat sink to draw heat away from LED circuit board 152 including the circuitry for LED array 158 to the center of elongated housing 142 and thereby dissipating the heat at the two ends 148A and 148B of tubular wall 144. Optional support member 164 defines cooling holes or holes 166 to allow heat from LED array 158 to flow into the center area of tubular wall 144 and from there to be dissipated at tubular circular ends 148A and 148B.

[0294] The sectional view of FIG. 13 taken through a typical single LED row 168 comprises ten individual LEDs 170 of the fifteen rows of LED array 158 is shown in FIG. 14. LED row 168 is circular in configuration, which is representative of each of the fifteen rows of LED array 158 as shown in FIG. 14. Each LED 170 includes an LED light emitting lens portion 172, an LED body portion 174, and an LED base portion 176. A cylindrical space 178 is defined between exterior side 156B of circuit board 152 and cylindrical tubular wall 144. Each LED 170 is positioned in space 178 as seen in the detailed view of FIG. 13A, which is devoid of optional support member 164. LED lens portion 172 is positioned in proximity with the inner surface of tubular wall 144, and LED base portion 176 is mounted proximate to the outer surface of LED array circuit board 152 in electrical contact with electrical elements thereon in a manner known in the art. A detailed view in FIG. 13A of a single LED 170 shows a rigid LED electrical lead 180 extending from LED base portion 176 to LED array circuit board 152 for electrical connection therewith. Lead 180 is secured to LED array circuit board 152 by solder 182. An LED center line 184 is aligned transverse to center line 146 of tubular wall 144 and as seen in FIG. 13A in particular perpendicular to center line 146. As shown in the sectional view of FIG. 13, light is emitted through tubular wall 144 by the ten LEDs 170 in equal strength about the entire circumference of tubular wall 144. Projection of this arrangement is such that all fifteen LED rows 168 are likewise arranged to emit light rays in equal strength the entire length of tubular wall 144 in equal strength about the entire 360-degree circumference of tubular wall 144. The distance between LED center line 184 and LED circuit board 152 is the shortest that is geometrically possible. FIG. 13A indicates a tangential line 186 relative to the cylindrical inner surface of tubular wall 144 in phantom line at the apex of LED lens portion 172 that is perpendicular to LED center line 184 so that all LEDs 170 emit light through tubular wall 144 in a direction perpendicular to tangential line 186 so that maximum illumination is obtained from all LEDs 170. Each LED 170 is designed to operate within a specified LED operating voltage capacity.

[0295] FIG. 14 shows a complete electrical circuit for LED lamp 124, which is shown in a schematic format that is flat for purposes of exposition. The complete LED circuit comprises two major circuit assemblies, namely, existing

ballast circuitry 188, which includes starter circuit 188A, and LED circuitry 190. LED circuitry 190 includes integral electronics circuitry 192A and 192B, which are associated with integral electronics circuit boards 160A and 160B. LED circuitry 190 also includes an LED array circuitry 190A and an LED array voltage protection circuit 190B.

[0296] When electrical power, normally 120 volt VAC or 240 VAC at 50 or 60 Hz is applied to rapid start ballast assembly 130, existing ballast circuitry 188 provides an AC or DC voltage with a fixed current limit across ballast socket electrical contacts 136A and 136B, which is conducted through LED circuitry 190 by way of LED circuit bi-pin electrical contacts 140A and 140B, respectively, (or in the event of the contacts being reversed, by way of LED circuit bi-pin contacts 138A and 138B) to the input of bridge rectifiers 194A and 194B, respectively.

[0297] Ballast assembly 130 limits the current going into LED lamp 124. Such limitation is ideal for the present embodiment of the inventive LED lamp 124 because LEDs in general are current driven devices and are independent of the driving voltage, that is, the driving voltage does not affect LEDs. The actual number of LEDs 170 will vary in accordance with the actual ballast assembly 130 used. In the example of the embodiment of LED lamp 124, ballast assembly 130 provides a maximum current limit of 300 mA.

[0298] Voltage surge absorbers 196A, 196B, 196C and 196D are positioned on LED voltage protection circuit 190B for LED array circuitry 190A in electrical association with integral electronics control circuitry 192A and 192B. Bridge rectifiers 194A and 194B are connected to the anode and cathode end buses, respectively of LED circuitry 190 and provide a positive voltage V+ and a negative voltage V-, respectively as is also shown in FIGS. 16 and 17. FIGS. 16 and 17 also show schematic details of integral electronics circuitry 192A and 192B. As seen in FIGS. 16 and 17, an optional resettable fuse 198 is integrated with integral electronics circuitry 192A. Resettable fuse 198 provides current protection for LED array circuitry 190A. Resettable fuse 198 is normally closed and will open and de-energize LED array circuitry 190A in the event the current exceeds the current allowed. The value for resettable fuse 198 is equal to or is lower than the maximum current limit of ballast assembly 130. Resettable fuse 198 will reset automatically after a cool down period.

[0299] When ballast assembly 130 is first energized, starter 130A may close creating a low impedance path from bi-pin electrical contact 138A to bi-pin electrical contact 138B, which is normally used to briefly heat the filaments in a fluorescent lamp in order to help the establishment of conductive phosphor gas. Such electrical action is unnecessary for LED lamp 124, and for that reason such electrical connection is disconnected from LED circuitry 190 by way of the biasing of bridge rectifiers 194A and 194B.

[0300] LED array circuitry 190A includes fifteen electrical circuit strings 200 individually designated as strings 200A, 200B, 200C, 200D, 200E, 200F, 200G, 200H, 200I, 200J, 200K, 200L, 200M, 200N and 200O all in parallel relationship with each string 200A-200O being electrically wired in series. Parallel strings 200 are so positioned and arranged so that each of the fifteen strings 200A-O is equidistant from one another. LED array circuitry 190A provides for ten LEDs 170 electrically mounted in series to each of the

fifteen parallel strings **200** for a total of one hundred and fifty LEDs **170** that constitute LED array **158**. LEDs **170** are positioned in equidistant relationship with one another and extend substantially the length of tubular wall **144**, that is, generally between tubular wall ends **148A** and **148B**. As shown in **FIG. 14**, each of strings **200A-200O** includes a resistor **202A-202O** in alignment with strings **200A-200O** connected in series to the anode end of each LED string **200** for a total of fifteen resistors **202**. The current limiting resistors **202A-202O** are purely optional, because the existing fluorescent ballast used here is already a current limiting device. The resistors **202A-202O** then serve as secondary protection devices. A higher number of individual LEDs **170** can be connected in series at each LED string **200**. The maximum number of LEDs **170** being configured around the circumference of the 1.5-inch diameter of tubular wall **144** in the particular example herein of LED lamp **124** is ten. Each LED **170** is configured with the anode towards the positive voltage **V+** and the cathode towards the negative voltage **V-**. When ballast **130** is energized, positive voltage that is applied through resistors **202** to the anode end of circuit strings **200** and the negative voltage that is applied to the cathode end of circuit strings **200** will forward bias LEDs **170** connected to circuit strings **200A-200O** and cause LEDs **170** to turn on and emit light.

[0301] Ballast assembly **130** regulates the electrical current through LEDs **170** to the correct value of 20 mA for each LED **170**. The fifteen LED strings **200** equally divide the total current applied to LED array circuitry **190A**. Those skilled in the art will appreciate that different ballasts provide different current outputs.

[0302] If the forward drive current for LEDs **170** is known, then the output current of ballast assembly **130** divided by the forward drive current gives the exact number of parallel strings of LEDs **170** in the particular LED array, here LED array **158**. The total number of LEDs in series within each LED string **200** is arbitrary since each LED **170** in each LED string **200** will see the same current. Again in this example, ten LEDs **170** are shown connected in each series LED string **200** because only ten LEDs **170** of the 5 mm discrete type of LED will fit around the circumference of a 1.5-inch diameter lamp housing. Ballast assembly **130** provides 300 mA of current, which when divided by the fifteen strings **200** of ten LEDs **170** per LED string **200** gives 20 mA per LED string **200**. Each of the ten LEDs **170** connected in series within each LED string **200** sees this 20 mA. In accordance with the type of ballast assembly **130** used, when ballast assembly **130** is first energized, a high voltage may be applied momentarily across ballast socket contacts **136A** and **136B**, which conducts to bi-pin contacts **140A** and **140B** (or **138A** and **138B**). This is normally used to help ignite a fluorescent tube and establish conductive phosphor gas, but is unnecessary for this circuit and is absorbed by voltage surge absorbers **196A**, **196B**, **196C**, and **196D** to limit the high voltage to an acceptable level for the circuit.

[0303] As can be seen from **FIG. 14A**, there can be more than ten LEDs **170** connected in series within each string **200A-200O**. There are twenty LEDs **170** in this example, but there can be more LEDs **170** connected in series within each string **200A-200O**. The first ten LEDs **170** of each parallel string will fill the first 1.5-inch diameter of the circumference of tubular wall **144**, the second ten LEDs **170**

of the same parallel string will fill the next adjacent 1.5-inch diameter of the circumference of tubular wall **144**, and so on until the entire length of the tubular wall **144** is substantially filled with all LEDs **170** comprising the total LED array **158**.

[0304] LED array circuitry **190A** includes fifteen electrical strings **200** individually designated as strings **200A**, **200B**, **200C**, **200D**, **200E**, **200F**, **200G**, **200H**, **200I**, **200J**, **200K**, **200L**, **200M**, **200N** and **200O** all in parallel relationship with all LEDs **170** within each string **200A-200O** being electrically wired in series. Parallel strings **200** are so positioned and arranged that each of the fifteen strings **200** is equidistant from one another. LED array circuitry **190A** includes twenty LEDs **170** electrically mounted in series within each of the fifteen parallel strings of LEDs **200A-O** for a total of three-hundred LEDs **170** that constitute LED array **158**. LEDs **170** are positioned in equidistant relationship with one another and extend generally the length of tubular wall **144**, that is, generally between tubular wall ends **148A** and **148B**. As shown in **FIG. 14A**, each of strings **200A-200O** includes an optional resistor **202** designated individually as resistors **202A**, **202B**, **202C**, **202D**, **202E**, **202F**, **202G**, **202H**, **202I**, **202J**, **202K**, **202L**, **202M**, **202N**, and **202O** in respective series alignment with strings **200A-200O** at the current input for a total of fifteen resistors **202**. Again, a higher number of individual LEDs **170** can be connected in series within each LED string **200**. The maximum number of LEDs **170** being configured around the circumference of the 1.5-inch diameter of tubular wall **144** in the particular example herein of LED lamp **124** is ten. Each LED **170** is configured with the anode towards the positive voltage **V+** and the cathode towards the negative voltage **V-**. When LED array circuitry **190A** is energized, the positive voltage that is applied through resistors **202A-202O** to the anode end circuit strings **200A-200O** and the negative voltage that is applied to the cathode end of circuit strings **200A-200O** will forward bias LEDs **170** connected to strings **200A-200O** and cause LEDs **170** to turn on and emit light.

[0305] Ballast assembly **130** regulates the electrical current through LEDs **170** to the correct value of 20 mA for each LED **170**. The fifteen LED strings **200** equally divide the total current applied to LED array circuitry **190A**. Those skilled in the art will appreciate that different ballasts provide different current outputs.

[0306] If the forward drive current for LEDs **170** is known, then the output current of ballast assembly **130** divided by the forward drive current gives the exact number of parallel strings of LEDs **170** in the particular LED array, here LED array **158**. The total number of LEDs in series within each LED string **200** is arbitrary since each LED **170** in each LED string **200** will see the same current. Again in this example, twenty LEDs **170** are shown connected in series within each LED string **200** because of the fact that only ten LEDs **170** of the 5 mm discrete type of LED will fit around the circumference of a 1.5-inch diameter lamp housing. Ballast assembly **130** provides 300 mA of current, which when divided by the fifteen strings **200** of ten LEDs **170** per LED string **200** gives 20 mA per LED string **200**. Each of the twenty LEDs **170** connected in series within each LED string **200** sees this 20 mA. In accordance with the type of ballast assembly **130** used, when ballast assembly **130** is first energized, a high voltage may be applied momentarily across ballast socket contacts **134A**, **136A** and **134B**, **136B**, which conduct to pin contacts **138A**, **140A** and

138B, 140B. Such high voltage is normally used to help ignite a fluorescent tube and establish conductive phosphor gas, but high voltage is unnecessary for LED array circuitry **190A** and voltage surge absorbers **196A, 196B, 196C,** and **196D** suppress the voltage applied by ballast circuitry **190**, so that the initial high voltage supplied is limited to an acceptable level for the circuit.

[0307] FIG. 14B shows another alternate arrangement of LED array circuitry **190A**. LED array circuitry **190A** consists of a single LED string **200** of LEDs **170** including for exposition purposes only, forty LEDs **170** all electrically connected in series. Positive voltage $V+$ is connected to optional resettable fuse **198**, which in turn is connected to one side of current limiting resistor **202**. The anode of the first LED in the series string is then connected to the other end of resistor **202**. A number other than forty LEDs **170** can be connected within the series LED string **200** to fill up the entire length of the tubular wall of the present invention. The cathode of the first LED **170** in the series LED string **200** is connected to the anode of the second LED **170**; the cathode of the second LED **170** in the series LED string **200** is then connected to the anode of the third LED **170**, and so forth. The cathode of the last LED **170** in the series LED string **200** is likewise connected to ground or the negative potential $V-$. The individual LEDs **170** in the single series LED string **200** are so positioned and arranged such that each of the forty LEDs is spaced equidistant from one another substantially filling the entire length of the tubular wall **144**. LEDs **170** are positioned in equidistant relationship with one another and extend substantially the length of tubular wall **144**, that is, generally between tubular wall ends **148A** and **148B**. As shown in **FIG. 14B**, the single series LED string **200** includes an optional resistor **202** in respective series alignment with single series LED string **200** at the current input. Each LED **170** is configured with the anode towards the positive voltage $V+$ and the cathode towards the negative voltage $V-$. When LED array circuitry **190A** is energized, the positive voltage that is applied through resistor **202** to the anode end of single series LED string **200** and the negative voltage that is applied to the cathode end of single series LED string **200** will forward bias LEDs **170** connected in series within single series LED string **200**, and cause LEDs **170** to turn on and emit light.

[0308] The present invention works ideally with the brighter high flux white LEDs available from Lumileds and Nichia in the SMD packages. Since these new devices require more current to drive them and run on low voltages, the high current available from existing fluorescent ballast outputs with current outputs of 300 mA and higher, along with their characteristically higher voltage outputs provide the perfect match for the present invention. The LEDs **170** have to be connected in series, so that each LED **170** within the same single LED string **200** will see the same current and therefore output the same brightness. The total voltage required by all the LEDs **170** within the same single LED string **200** is equal to the sum of all the individual voltage drops across each LED **170** and should be less than the maximum voltage output of ballast assembly **130**.

[0309] The single LED string **200** of SMD LEDs **170** connected in series can be mounted onto a long thin strip flexible circuit board made of polyimide or equivalent material. The flexible circuit board **152** is then spirally wrapped into a generally cylindrical configuration. Although

this embodiment describes a generally cylindrical configuration, it can be appreciated by someone skilled in the art to form the flexible circuit board **152** into shapes other than a cylinder, such as an elongated oval, triangle, rectangle, hexagon, and octagon, as examples of a wide possibility of configurations. Accordingly, the shape of the tubular housing **142** holding the single wrapped flexible circuit board **152** can be made in a similar shape to match the shape of the formed flexible circuit board **152** configuration.

[0310] LED array circuit board **152** is positioned and held within tubular wall **144**. As in **FIGS. 12 and 15**, LED array circuit board **152** has opposed circuit board circular ends **154A** and **154B** that are slightly inwardly positioned from tubular wall ends **148A** and **148B**, respectively. LED array circuit board **152** has interior and exterior cylindrical sides **156A** and **156B**, respectively with interior side **156A** forming an elongated central passage **157** between tubular wall circular ends **148A** and **148B** with exterior side **156B** being spaced from tubular wall **144**. LED array circuit board **152** is preferably assembled from a material that has a flat preassembled unbiased mode and an assembled self-biased mode wherein cylindrical sides **156A** and **156B** press outwardly towards tubular wall **144**. The SMD LEDs **170** are mounted on exterior cylindrical side **156B** with the lens **54** of each LED in juxtaposition with tubular wall **25** and pointing radially outward from center line **146**. As shown in the sectional view of **FIG. 13**, light is emitted through tubular wall **144** by the LEDs **170** in equal strength about the entire 360-degree circumference of tubular wall **144**.

[0311] As described earlier in **FIGS. 12 and 15**, an optional support member **164** is made of an electrically non-conductive material such as rubber or plastic and is rigid in its position. It is preferably made of a self-biasable material and is in a biased mode in the cylindrical position, so that it presses radially outward in support of cylindrical LED array electrical LED array circuit board **152**. Optional support member **164** is longitudinally aligned with tubular center line **146** of tubular member **144**. Optional support member **164** further isolates integral electronics circuit boards **42A** and **42B** from LED array circuit board **152** containing the compact LED array **158**. Optional support member **164**, which is preferably made of a heat conducting material, may operate as a heat sink to draw heat away from LED array circuit board **152** and LED array **158** to the center of elongated housing **142** and thereby dissipating the heat out at the two ends **148A** and **148B** of tubular wall **144**. Optional support member **164** defines cooling holes or holes **166** to allow heat from LED array **158** to flow to the center area of tubular wall **144** and from there to be dissipated at tubular circular ends **148A** and **148B**.

[0312] Ballast assembly **130** regulates the electrical current through LEDs **170** to the correct value of 300 mA or other ballast assembly **130** rated lamp current output for each LED **170**. The total current is applied to both the single LED string **200** and to LED array circuitry **190A**. Again, those skilled in the art will appreciate that different ballasts provide different rated lamp current outputs.

[0313] If the forward drive current for LEDs **170** is known, then the output current of ballast assembly **130** divided by the forward drive current gives the exact number of parallel strings **200** of LEDs **170** in the particular LED array, here LED array **158**. Since the forward drive current

for LEDs 170 is equal to the output current of ballast assembly 130, then the result is a single LED string 200 of LEDs 170. The total number of LEDs in series within each LED string 200 is arbitrary since each LED 170 in each LED string 200 will see the same current. Again in this example, forty LEDs 170 are shown connected within each series LED string 200. Ballast assembly 130 provides 300 mA of current, which when divided by the single LED string 200 of forty LEDs 170 gives 300 mA for single LED string 200. Each of the forty LEDs 170 connected in series within single LED string 200 sees this 300 mA. In accordance with the type of ballast assembly 130 used, when ballast assembly 130 is first energized, a high voltage may be applied momentarily across ballast socket contacts 134A, 136A and 134B, 136B, which conduct to pin contacts 138A, 140A and 138B, 140B. Such high voltage is normally used to help ignite a fluorescent tube and establish conductive phosphor gas, but high voltage is unnecessary for LED array circuitry 190A and voltage surge absorbers 196A, 196B, 196C, and 196D suppress the voltage applied by ballast circuitry 70, so that the initial high voltage supplied is limited to an acceptable level for the circuit.

[0314] It can be seen from someone skilled in the art from FIGS. 14, 14A, and 14B that the LED array 158 can consist of at least one parallel electrical LED string 200 containing at least one LED 170 connected in series within the parallel electrical LED string 200. Therefore, the LED array 158 can consist of any number of parallel electrical strings 200 combined with any number of LEDs 170 connected in series within electrical strings 200, or any combinations thereof.

[0315] FIG. 14C shows a simplified arrangement of the LED array circuitry 190A of LEDs 170 shown for purposes of exposition in a flat compressed position for the overall electrical circuit shown in FIG. 14. AC lead lines 212A, 212B and 214A, 214B and DC positive lead lines 216A, 216B and DC negative lead lines 218A, 218B are connected to integral electronics circuit boards 160A and 160B by way of 6-pin headers 162A and 162B and connectors 161A-161D. Four parallel LED strings 200 each including a resistor 202 are each connected to DC positive lead lines 216A, 216B on one side, and to LED positive lead line 216 or the anode side of each LED 170 and on the other side. The cathode side of each LED 170 is then connected to LED negative lead line 218 and to DC negative lead lines 218A, 218B directly. AC lead lines 212A, 212B and 214A, 214B simply pass through LED array circuitry 190A.

[0316] FIG. 14D shows a simplified arrangement of the LED array circuitry 190A of LEDs 170 shown for purposes of exposition in a flat compressed position for the overall electrical circuit shown in FIG. 14A. AC lead lines 212A, 212B and 214A, 214B and DC positive lead lines 216A, 216B and DC negative lead lines 218A, 218B are connected to integral electronics boards 160A and 160B by way of 6-pin headers 162A and 162B and connectors 161A-161D. Two parallel LED strings 200 each including a single resistor 202 are each connected to DC positive lead lines 216A, 216B on one side, and to LED positive lead line 216 or the anode side of the first LED 170 in each LED string 200 on the other side. The cathode side of the first LED 170 is connected to LED negative lead line 218 and to adjacent LED positive lead line 216 or the anode side of the second LED 170 in the same LED string 200. The cathode side of the second LED 170 is then connected to LED negative lead

line 218 and to DC negative lead lines 218A, 218B directly in the same LED string 200. AC lead lines 212A, 212B and 214A, 214B simply pass through LED array circuitry 190A.

[0317] FIG. 14E shows a simplified arrangement of the LED array circuitry 190A of LEDs 170 shown for purposes of exposition in a flat compressed position for the overall electrical circuit shown in FIG. 14B. AC lead lines 212A, 212B and 214A, 214B and DC positive lead lines 216A, 216B and DC negative lead lines 218A, 218B are connected to integral electronics boards 160A and 160B by way of 6-pin headers 162A and 162B and connectors 161A-161D. Single parallel LED string 200 including a single resistor 202 is connected to DC positive lead lines 216A, 216B on one side, and to LED positive lead line 216 or the anode side of the first LED 170 in the LED string 200 on the other side. The cathode side of the first LED 170 is connected to LED negative lead line 218 and to adjacent LED positive lead line 216 or the anode side of the second LED 170. The cathode side of the second LED 170 is connected to LED negative lead line 218 and to adjacent LED positive lead line 216 or the anode side of the third LED 170. The cathode side of the third LED 170 is connected to LED negative lead line 218 and to adjacent LED positive lead line 216 or the anode side of the fourth LED 170. The cathode side of the fourth LED 170 is then connected to LED negative lead line 218 and to DC negative lead lines 218A, 218B directly. AC lead lines 212A, 212B and 214A, 214B simply pass through LED array circuitry 190A.

[0318] With the new high-brightness LEDs in mind, FIG. 14F shows a single high-brightness LED 171Z positioned on an electrical string in what is defined herein as an electrical series arrangement for the overall electrical circuit shown in FIG. 14 and also analogous to FIG. 14B. The single high-brightness LED 171Z fulfills a particular lighting requirement formerly fulfilled by a fluorescent lamp.

[0319] Likewise, FIG. 14G shows two high-brightness LEDs 171Z in electrical parallel arrangement with one high-brightness LED 171Z positioned on each of the two parallel strings for the overall electrical circuit shown in FIG. 14 and also analogous to the electrical circuit shown in FIG. 14A. The two high-brightness LEDs 171Z fulfill a particular lighting requirement formerly fulfilled by a fluorescent lamp.

[0320] As shown in the schematic electrical and structural representations of FIG. 15, circuit board 152 for LED array 158 which has mounted thereon LED array circuitry 190A is positioned between integral electronics circuit boards 160A and 160B that in turn are electrically connected to ballast assembly circuitry 188 by bi-pin electrical contacts 138A, 140A and 138B, 140B, respectively, which are mounted to base end caps 150A and 150B, respectively. Bi-pin contact 138A includes an external extension 204A that protrudes externally outwardly from base end cap 150A for electrical connection with ballast socket contact 134A and an internal extension 204B that protrudes inwardly from base end cap 150A for electrical connection to integral electronics circuit boards 160A. Bi-pin contact 140A includes an external extension 206A that protrudes externally outwardly from base end cap 150A for electrical connection with ballast socket contact 136A and an internal extension 206B that protrudes inwardly from base end cap 150A for electrical connection to integral electronics circuit boards 160A. Bi-

pin contact 138B includes an external extension 208A that protrudes externally outwardly from base end cap 150B for electrical connection with ballast socket contact 134B and an internal extension 208B that protrudes inwardly from base end cap 150B for electrical connection to integral electronics circuit board 160B. Bi-pin contact 140B includes an external extension 210A that protrudes externally outwardly from base end cap 150B for electrical connection with ballast socket contact 136B and an internal extension 210B that protrudes inwardly from base end cap 150B for electrical connection to integral electronics circuit board 160B. Bi-pin contacts 138A, 140A, 138B, and 140B are soldered directly to integral electronics circuit boards 160A and 160B, respectively. In particular, bi-pin contact extensions 204A and 206A are associated with bi-pin contacts 138A and 140A, respectively, and bi-pin contact extensions 208A and 210A are associated with bi-pin contacts 138B and 140B, respectively. Being soldered directly to integral electronics circuit board 160A electrically connects bi-pin contact extensions 204B and 206B. Similarly, being soldered directly to integral electronics circuit board 160B electrically connects bi-pin contact extensions 208B and 210B. 6-pin header 162A is shown positioned between and in electrical connection with integral electronics circuit board 160A and LED array circuit board 152 and LED array circuitry 190A mounted thereon as shown in FIG. 14. 6-pin header 162B is shown positioned between and in electrical connection with integral electronics circuit board 160B and LED array circuit board 152 and LED array circuitry 190A mounted thereon.

[0321] FIG. 16 shows a schematic of integral electronics circuit 192A mounted on integral electronics circuit board 160A. Integral electronics circuit 192A is also indicated in part in FIG. 14 as connected to LED array circuitry 190A. Integral electronics circuit 192A is in electrical contact with bi-pin contacts 138A, 140A, which are shown as providing either AC or DC voltage. Integral electronics circuit 192A includes bridge rectifier 194A, voltage surge absorbers 196A and 196C, and resettable fuse 198. Integral electronic circuit 192A leads to or from LED array circuitry 190A. It is noted that FIG. 16 indicates the presence of possible AC voltage (rather than possible DC voltage) by an AC wave symbol ~. Each AC voltage could be DC voltage supplied by certain ballast assemblies 188 as mentioned earlier herein. In such a case DC voltage would be supplied to LED array 158 even in the presence of bridge rectifier 194A. It is particularly noted that in such a case, voltage surge absorbers 196A and 196C would remain operative. AC lead lines 212A and 214A are in a power connection with ballast assembly 188. DC lead lines 216A and 218A are in positive and negative direct current relationship with LED array circuitry 190A. Bridge rectifier 194A is in electrical connection with four lead lines 212A, 214A, 216A and 218A. A voltage surge absorber 196A is in electrical contact with lead lines 212A and 214A and voltage surge absorber 196C is positioned on lead line 212A. Lead lines 216A and 218A are in electrical contact with bridge rectifier 194A and in power connection with LED array circuitry 190A. Fuse 198 is positioned on lead line 216A between bridge rectifier 194A and LED array circuitry 190A.

[0322] FIG. 17 shows a schematic of integral electronics circuit 192B mounted on integral electronics circuit board 160B. Integral electronics circuit 192B is also indicated in part in FIG. 14 as connected to LED array circuitry 190A.

Integral electronics circuit 192B is a close mirror image or electronics circuit 192A mutatis mutandis. Integral electronics circuit 192B is in electrical contact with bi-pin contacts 138B, 140B, which are shown as providing either AC or DC voltage. Integral electronics circuit 192B includes bridge rectifier 194B, voltage surge absorbers 196B and 196D. Integral electronic circuit 192B leads to or from LED array circuitry 190A. It is noted that FIG. 17 indicates the presence of possible AC voltage (rather than possible DC voltage) by an AC wave symbol ~. Each AC voltage could be DC voltage supplied by certain ballast assemblies 188 as mentioned earlier herein. In such a case DC voltage would be supplied to LED array 158 even in the presence of bridge rectifier 194B. It is particularly noted that in such a case, voltage surge absorbers 196B and 196D would remain operative. AC lead lines 212B and 214B are in a power connection with ballast assembly 188. DC lead lines 216B and 218B are in positive and negative direct current relationship with LED array circuitry 190A. Bridge rectifier 194B is in electrical connection with four lead lines 212B, 214B, 216B and 218B. A voltage surge absorber 196B is in electrical contact with lead lines 212B and 214B and voltage surge absorber 196D is positioned on lead line 214B. Lead lines 216B and 218B are in electrical contact with bridge rectifier 194B and in power connection with LED array circuitry 190A.

[0323] FIGS. 16 and 17 show the lead lines going into and out of LED circuitry 190 respectively. The lead lines include AC lead lines 212B and 214B, positive DC voltage 216B, and DC negative voltage 218B. The AC lead lines 212B and 214B are basically feeding through LED circuitry 190, while the positive DC voltage lead line 216B and negative DC voltage lead line 218B are used primarily to power the LED array 158. DC positive lead lines 216A and 216B are the same as LED positive lead line 216 and DC negative lead lines 218A and 218B are the same as LED negative lead line 218. LED array circuitry 190A therefore consists of all electrical components and internal wiring and connections required to provide proper operating voltages and currents to LEDs 170 connected in parallel, series, or any combinations of the two.

[0324] FIGS. 18 and 18A show the optional support member 164 with cooling holes 166 in both side and cross-sectional views respectively.

[0325] FIG. 19 shows an isolated top view of one of the base end caps, namely, base end cap 150A, which is analogous to base end cap 150B, mutatis mutandis. Bi-pin electrical contacts 138A, 140A extend directly through base end cap 150A in the longitudinal direction in alignment with center line 146 of tubular wall 144 with bi-pin external extensions 204A, 206A and internal extensions 204B, 206B shown. Base end cap 150A is a solid cylinder in configuration as seen in FIGS. 19 and 19A and forms an outer cylindrical wall 220 that is concentric with center line 146 of tubular wall 144 and has opposed flat end walls 222A and 222B that are perpendicular to center line 146. Two cylindrical parallel vent holes 224A and 224B are defined between end walls 222A and 222B in vertical alignment with center line 146.

[0326] As also seen in FIG. 19A, base end cap 150A defines an outer circular slot 226 that is concentric with center line 146 of tubular wall 144 and concentric with and

aligned proximate to circular wall 220. Outer circular slot 226 is of such a width and circular end 148A of tubular wall 144 is of such a thickness and diameter that outer circular slot 226 accepts circular end 148A into a fitting relationship and circular end 148A is thus supported by circular slot 226. Base end cap 150B defines another outer circular slot (not shown) analogous to outer circular slot 226 that is likewise concentric with center line 146 of tubular wall 144 so that circular end 148B of tubular wall 144 can be fitted into the analogous circular slot of base end cap 150B wherein circular end 148B of tubular wall 144 is also supported. In this manner tubular wall 144 is mounted to end caps 150A and 150B.

[0327] As also seen in FIG. 19A, base end cap 150A defines an inner circular slot 228 that is concentric with center line 146 of tubular wall 144 and concentric with and spaced radially inward from outer circular slot 226. Inner circular slot 228 is spaced from outer circular slot 226 at such a distance that would be occupied by LEDs 170 mounted to LED circuit board 152 within tubular wall 144. Inner circular slot 228 is of such a width and diameter and circular end 154A of LED circuit board 152 is of such a thickness and diameter that circular end 154A is fitted into inner circular slot 228 and is thus supported by inner circular slot 228. Base end cap 150B defines another outer circular slot (not shown) analogous to outer circular slot 226 that is likewise concentric with center line 146 of tubular wall 144 so that circular end 154B of LED circuit board 152 can be fitted into the analogous inner circular slot of base end cap 150B wherein circular end 154B is also supported. In this manner LED circuit board 152 is mounted to end caps 150A and 150B.

[0328] Circular ends 148A and 148B of tubular wall 144 and also circular ends 154A and 154B of LED circuit board 152 are secured to base end caps 150A and 150B preferably by gluing in a manner known in the art. Other securing methods known in the art of attaching such as cross-pins or snaps can be used.

[0329] An analogous circular slot (not shown) concentric with center line 146 is optionally formed in flat end walls 222A and 222B of base end cap 150A and an analogous circular slot in the flat end walls of base end cap 150B for insertion of the opposed ends of optional support member 164 so that optional support member 164 is likewise supported by base end caps 150A and 150B. Circular ends 148A and 148B of tubular wall 144 are optionally press fitted to circular slot 226 of base end cap 150A and the analogous circular slot of base end cap 150B.

[0330] FIG. 20 is a sectional view of an alternate LED lamp mounted to tubular wall 144A that is a version of LED lamp 124 as shown in FIG. 13. The sectional view of LED lamp 230 shows a single row 168A of the LEDs of LED lamp 230 and includes a total of six LEDs 170, with four LEDs 170X being positioned at equal intervals at the bottom area 232 of tubular wall 144A and with two LEDs 170Y being positioned at opposed side areas 234 of tubular wall 144A. LED circuitry 190 previously described with reference to LED lamp 124 would be the same for LED lamp 230. That is, all fifteen strings 200 of LED array 158 of LED lamp 124 would be the same for LED lamp 230 except that a total of ninety LEDs 170 would comprise LED lamp 230 with the ninety LEDs 170 positioned at strings 200 at such

electrical connectors that would correspond with LEDs 170X and 170Y throughout. The reduction to ninety LEDs 170 of LED lamp 230 from the one hundred and fifty LEDs 170 of LED lamp 124 would result in a forty percent reduction of power demand with an illumination result that would be satisfactory under certain circumstances. Stiffening of circuit board for LED lamp 230 is accomplished by circular slot 228 for tubular wall 144A or optionally by the additional placement of LEDs 170 (not shown) at the top vertical position in space 178 or optionally a vertical stiffening member 236 shown in phantom line that is positioned vertically over center line 146 of tubular wall 144A at the upper area of space 178 between LED circuit board 152 and the inner side of tubular wall 144A and extends the length of tubular wall 144A and LED circuit board 152.

[0331] LED lamp 124 as described above will work for both AC and DC voltage outputs from an existing fluorescent ballast assembly 130. In summary, LED array 158 will ultimately be powered by DC voltage. If existing fluorescent ballast assembly 130 operates with an AC output, bridge rectifiers 194A and 194B convert the AC voltage to DC voltage. Likewise, if existing fluorescent ballast 130 operates with a DC voltage, the DC voltage remains a DC voltage even after passing through bridge rectifiers 194A and 194B.

[0332] FIGS. 21 and 22 show a top view of a horizontally aligned curved LED lamp 238 that is secured to an existing fluorescent fixture 240 schematically illustrated in phantom line including existing fluorescent ballast 242 that in turn is mounted in a vertical wall 244. Fluorescent ballast 242 can be either an electronic instant start or rapid start, a hybrid, or a magnetic ballast assembly for the purposes of illustrating the inventive curved LED lamp 238, which is analogous to and includes mutatis mutandis the variations discussed herein relating to linear LED lamps 10 and 124.

[0333] Curved LED lamp 238 is generally hemispherical, or U-shaped, as viewed from above and is of a type of LED lamp that can be used as lighting over a mirror, for example, or for decorative purposes, or for other uses when such a shape of LED lamp would be retrofitted to an existing fluorescent lamp fixture.

[0334] LED lamp 238 as shown in FIGS. 21 and 21A includes a curved housing 246 comprising a curved hemispherical tubular wall 248 having a center line 249 and tubular ends 250A and 250B. A pair of end caps 252A and 252B secured to tubular ends 250A and 250B, respectively, are provided with bi-pin electrical connectors 254A and 254B that are electrically connected to ballast double contact electrical sockets 256A and 256B in a manner previously described herein with regard to LED lamp 124. Base end caps 252A and 252B are such as those described in FIGS. 9A and 19A regarding LED lamps 10 and 124. Curved LED lamp 238 includes a curved circuit board 258 that supports an LED array 260 mounted thereon comprising twenty eight individual LEDs 262 positioned at equal intervals. Curved circuit board 258 is tubular and hemispherical and is positioned and held in tubular wall 248. Curved circuit board 258 forms a curved central cylindrical passage 264 that extends between the ends of tubular wall 248 and opens at tubular wall ends 250A and 250B for exhaust of heat generated by LED array 260. Curved circuit board 258 has

opposed circuit board circular ends that are slightly inwardly positioned from tubular wall ends **250A** and **250B**, respectively.

[0335] Fifteen parallel electrical strings are displayed and described herein. In particular, fifteen rows **264** of four LEDs **262** are positioned in tubular wall **248**. LED lamp **238** is provided with integral electronics (not shown) analogous to integral electronic circuits **192A** and **192B** described previously for LED lamp **124**. Ballast circuitry and LED circuitry are analogous to those described with regard to LED lamp **124**, namely, ballast circuitry **188**, starter circuit **188A**, LED circuitry **190** and LED array circuitry **190A**. The LED array circuit for curved LED lamp **124** is mounted on the exterior side **270A** of circuit board **258**. In particular, fifteen parallel electrical strings for each one of the fifteen LED rows **266** comprising four LEDs **262** positioned within curved tubular wall **248** are mounted on curved circuit board **258**. As seen in FIG. 21, curved tubular wall **248** and curved circuit board **258** forms a hemispherical configuration about an axial center **268**. The electrical circuitry for curved LED lamp **238** is analogous to the electrical circuitry set forth herein for LED lamp **124** including LED array circuitry **190A** and the parallel electrical circuit strings **200** therein with the necessary changes having been made. The physical alignment of parallel electrical circuit strings **200** of LED array circuitry **190A** are parallel as shown in FIG. 14 and are radially extending in FIG. 21, but in both LED lamp **124** and curved LED lamp **238** the electrical structure of the parallel electrical circuit strings are both parallel in electrical relationship. The radial spreading of LED rows **266** outwardly extending relative to the axial center **268** of hemispherical shaped tubular wall **248** is coincidental with the physical radial spreading of the parallel electrical strings to which LED rows **266** are electrically connected.

[0336] Curved circuit board **258** has exterior and interior sides **270A** and **270B**, respectively, which are generally curved circular in cross-section as indicated in FIG. 21A. Although this embodiment describes a generally curved cylindrical configuration, it can be appreciated by someone skilled in the art to form the curved flexible circuit board **258** into shapes other than a cylinder for example, such as an elongated oval, triangle, rectangle, hexagon, octagon, etc. Accordingly, the shape of the curved tubular housing **246** holding the individual curved flexible circuit board **258** can be made in a similar shape to match the shape of the formed curved flexible circuit board **258** configuration. Exterior side **270A** is spaced from tubular wall **248** so as to define a curved space **272** there between in which LEDs **262** are positioned. Curved space **270** is toroidal in cross-section as shown in FIG. 21A. Each LED **262** includes an LED lens portion **274**, an LED body portion **276**, and an LED base portion **278** with LED **262** having an LED center line **279**. LEDs **262** are positioned in curved tubular wall **248** aligned to center line **249** of curved tubular wall **248** relative to a plane defined by each LED row **266**. Lens portion **274** is in juxtaposition with curved tubular wall **248** and base portion **278** is mounted to curved circuit board **258** in a manner previously described herein with regard to LED lamp **124**. LEDs **262** have LED center lines **279**.

[0337] Curved circuit board **258** is preferably made of a flexible material that is unbiased in a preassembled flat, and movable to an assembled self-biased mode. The latter as shown in the mounted position in FIGS. 21, 21A, and 22

wherein the exterior and internal sides **270A** and **270B** of curved board **258** presses outwardly towards curved tubular wall **248** in structural support of LEDs **262**.

[0338] As shown in the isolated view of curved circuit board **258** in FIG. 22 wherein curved circuit board **258** is in the biased mode as shown in FIGS. 21 and 21A, curved exterior side **270A** is stretched to accommodate the greater area that exterior side **270A** must encompass as compared to the area occupied by curved interior side **270B**. Exterior side **270A** defines a plurality of slits **280** that are formed lateral to the curved elongated orientation or direction of circuit board **258**, and slits **280** are formed transverse to the axial center. After circuit board **258** is rolled from the flat, unbiased mode to the rolled cylindrical mode, circuit board **258** is further curved from the rolled mode to the curved mode as shown in FIGS. 21, 21A, and 22. By this action, exterior side **270A** is stretched so that slits **280** become separated as shown in FIG. 22. Interior side **270B** in turn becomes compressed as shown. Curved circuit board **258** is made of a material that is both biasable to accommodate the stretchability of exterior wall **270A** and to some extent compressible to accommodate the compressed mode of interior wall **270B**.

[0339] Curved LED lamp **238** as described above is a bi-pin type connector LED lamp such as bi-pin type LED lamp **124** for purposes of exposition only. The basic features of LED lamp **238** as described above would likewise apply to a single-pin type LED lamp such as single-pin lamp **10** described herein.

[0340] The description of curved LED lamp **238** as a hemispherical LED is for purposes of exposition only and the principles expounded herein would be applicable in general to any curvature of a curved LED lamp including the provision of a plurality of slits **280** that would allow the stretching of the external side of a biasable circuit board.

[0341] FIG. 23 shows in an isolated circuit board **282** in a flat mode subsequent to having an LED circuitry mounted thereon and further subsequent to having LEDs mounted thereon and connected to the LED circuitry, and prior to assembly to insertion into a tubular housing analogous tubular housings **24**, **142**, and **246** of LED lamps **10**, **124**, and **238**. Circuit board **282** is a variation of LED array circuit board **34** of LED lamp **10**, circuit board **152** for LED lamp **114**, and circuit board **258** for LED lamp **238**. Circuit board **282** has a flat top side **284** and an opposed flat bottom side **286**. Circuit board **282** is rectangular in configuration having opposed linear end edges **288A** and **288B** and opposed linear side edges **290A** and **290B**. A total of twenty-five LEDs **292** are secured to top side **284** with each LED **292** being aligned perpendicular to flat top side **284**. LED circuitry consisting of pads, tracks and vias, etc. (not shown) to provide electrical power to LEDs **292** can be mounted to top side **284** or to bottom side **286**. Such LED circuitry is analogous to LED circuitry **70** for LED lamp **10** or LED circuitry **190** for LED lamp **124**, as the case may be. Such LED circuitry can be mounted directly to top side **284** or can be mounted to a separate thin, biasable circuit board that is in turn secured by gluing to top side **284** as shown in FIG. 25. A manner of mounting twenty-five LEDs **292** into an alternate LED matrix **294** to that shown in FIGS. 3A and 13A is shown by way of exposition as shown in FIG. 23. Five columns **296A**, **296B**, **296C**, **296D** and **296E** of three LEDs **292** each, and

five columns **298A**, **298B**, **298C**, **298D** and **298E** of two LEDs **292** each are aligned at equal intervals between columns **296A-E**. Matrix **294** further includes the same 25 LEDs **292** being further arranged in three rows **300A**, **300B**, and **300C** aligned at equal intervals, and in two rows **302A** and **302B** aligned at equal intervals between rows **300A-C**. LEDs **292** are connected to an LED electrical series parallel circuit. The staggered pattern of LEDs **292** shown in **FIG. 23** illustrates by way of exposition merely one of many possible patterns of placement of LEDs other than the LED pattern of placements shown in LED lamps **10**, **124**, and **238**.

[0342] As shown in **FIG. 24**, flat circuit board **282** with LEDs **292** is shown rolled into a cylindrical configuration indicated as cylindrical circuit board **304** in preparation for assembly into a tubular wall such as tubular walls **26** and **144** of LED lamps **10** and **124** previously described and also mutatis mutandis of LED lamp **238**. Flat top side **284** of flat circuit board **282** is shown as cylindrical exterior side **318** of cylindrical circuit board **304**; and flat bottom side **286** of flat circuit board **282** is shown as cylindrical interior side **320** of cylindrical circuit board **304**. The process of rolling flat circuit board **282** into cylindrical circuit board **304** can be done physically by hand, but is preferably done automatically by a machine.

[0343] A mating line **306** is shown at the juncture of linear side edges **290A** and **290B** shown in **FIG. 23**. The material of flat circuit board **282**, that is, of cylindrical circuit board **304**, is flexible to allow the cylindrical configuration of circuit board **304** and is resilient and self-biased. That is, circuit board **304** is moveable between a flat unbiased mode and a cylindrical biased mode, wherein the cylindrical biased mode circuit board **304** self-biases to return to its flat unbiased mode. As such, in the cylindrical mode, cylindrical circuit board **304** presses outwardly and thus presses LEDs **292** against the tubular wall in which it is positioned and held, as described previously with regard to LED lamps **10** and **124** wherein the LEDs themselves are pressed outwardly against such a tubular wall shown schematically in phantom line as tubular wall **308** in **FIG. 24**. Each LED **292** as previously discussed herein includes a lens portion **310**, a body portion **312**, and a base portion **314** so that lens portion **310** is pressed against tubular wall **306**.

[0344] **FIG. 25** shows an end view of a layered cylindrical circuit board **316** having opposed cylindrical interior and exterior sides **320** and **318** in isolation with a typical LED **324** shown for purposes of exposition mounted thereto in juxtaposition with a partially indicated tubular wall **326** analogous to tubular walls **26** for LED lamp **10** and tubular wall **144** for LED lamp **124** as described heretofore. Circuit board **316** is in general is analogous to circuit boards **34** in **FIG. 3** of LED lamp **10** and circuit board **152** in **FIG. 13** of LED lamp **124** with the proviso that circuit board **316** comprises two layers of material, namely cylindrical outer layer **322A** and a cylindrical inner support layer **322B**. Outer layer **322A** is a thin flexible layer of material to which is mounted an LED circuit such as either LED array circuitry **72** for LED lamp **10** or LED array circuitry **190A** for LED lamp **124**. Outer layer **322A** is attached to inner layer **322B** by a means known in the art, for example, by gluing. Inner support layer **322B** is made of a flexible material and preferably of a biasable material, and is in the biased mode when in a cylindrical position as shown in **FIG. 25**; and

outer layer **322A** is at least flexible prior to assembly and preferably is also made of a biasable material that is in the biased mode as shown in **FIG. 25**. Typical LED **324** is secured to outer layer **322A** in the manner shown earlier herein in **FIGS. 3** and **3A** of LED lamp **10** and LED lamp **124**. An LED array circuit (not shown) such as LED array circuitry **72** of LED lamp **10** and LED array circuitry **190A** for LED lamp **124** can be mounted on cylindrical outer layer **322A** prior to assembly of outer layer **322A** to inner layer **322B**. Typical LED **324** is electrically connected to the LED array circuitry mounted on outer layer **322A** and/or inner layer **322B**. Together outer layer **322A** and inner layer **322B** comprise circuit board **316**.

[0345] **FIGS. 26-35A** show another embodiment of the present invention, in particular an LED lamp **328** seen in **FIG. 26** retrofitted to an existing fluorescent fixture **330** mounted to a ceiling **332**. An electronic instant start type ballast assembly **334**, which can also be a hybrid, or a magnetic ballast assembly, is positioned within the upper portion of fixture **330**. Fixture **330** further includes a pair of fixture mounting portions **336A** and **336B** extending downwardly from the ends of fixture **330** that include ballast electrical contacts shown as ballast end sockets **338A** and **338B** that are in electrical contact with ballast assembly **334**. Fixture ballast end sockets **338A** and **338B** are each single contact sockets in accordance with the electrical operational requirement of an electronic instant start ballast, hybrid ballast, or one type of magnetic ballast. As also seen in **FIG. 26A**, LED lamp **328** includes opposed single-pin electrical contacts **340A** and **340B** that are positioned in ballast sockets **338A** and **338B**, respectively, so that LED lamp **328** is in electrical contact with ballast assembly **334**.

[0346] As shown in the disassembled mode of **FIG. 27**, LED lamp **328** includes an elongated housing **342** particularly configured as a linear tubular wall **344** circular in cross-section taken transverse to a center line **346** that is made of a translucent material such as plastic or glass and preferably having a diffused coating. Tubular wall **344** has opposed tubular wall ends **348A** and **348B**. LED lamp **328** further includes a pair of opposed lamp base end caps **352A** and **352B** mounted to single electrical contact pins **340A** and **340B**, respectively for insertion in ballast electrical socket contacts **338A** and **338B** in electrical power connection to ballast assembly **334**, so as to provide power to LED lamp **328**. Tubular wall **344** is mounted to opposed base end caps **352A** and **352B** at tubular wall ends **348A** and **348B** in the assembled mode as shown in **FIG. 26**. An integral electronics circuit board **354A** is positioned between base end cap **352A** and tubular wall end **348A**, and an integral electronics circuit board **354B** is positioned between base end cap **352B** and tubular wall end **348B**.

[0347] As seen in **FIGS. 27** and **28**, LED lamp **328** also includes a 6-pin connector **356A** connected to integral electronics circuit board **354A** and to a 6-pin header **358** on first disk **368**. LED lamp **328** also includes a 6-pin connector **356B** connected to integral electronics circuit board **354B** and to a 6-pin header **358** on last disk **368**.

[0348] For the purposes of exposition, only ten of the original fifteen parallel electrical strings are displayed and each LED electrical string **408** is herein described as containing LED row **360**. In particular, **FIG. 28** shows a typical single LED row **360** that includes ten individual LEDs **362**.

LED lamp 328 includes ten LED rows 360 that comprise LED array 366. FIG. 29 shows a partial view of six LEDs 362 of each of the ten LED rows 360. Each LED row 360 is circular in configuration, which is representative of each of the ten rows 360 of LED array 366 as shown in FIG. 29 with all LED rows 360 being aligned in parallel relationship.

[0349] In FIG. 29, ten circular disks 368 each having central circular apertures 372 and having opposed flat disk walls 370A and 370B and disk circular rims 370C are positioned and held in tubular wall 344 between tubular end walls 348A and 348B. Each disk 368 that is centrally aligned with center line 346 of tubular wall 344 defines a central circular aperture 372. Apertures 372 are provided for the passage of heat out of tubular wall 344 generated by LED array 366. Disks 368 are spaced apart at equal distances and are in parallel alignment. The inner side of tubular wall 344 defines ten equally spaced circular grooves 374 defining parallel circular configurations in which are positioned and held disk rims 370C.

[0350] Similar to FIG. 29, FIG. 29A now shows a single LED row 360 that includes one individual LED 362. LED lamp 328 includes ten LED rows 360 that can comprise LED array 366. FIG. 29A shows a single LED 362 of each of the ten LED rows 360 mounted in the center of each disk 368. A heat sink 396 is attached to each LED 362 to extract heat away from LED 362. Ten circular disks 368 each having opposed flat disk walls 370A and 370B and disk circular rims 370C are positioned and held in tubular wall 344 between tubular end walls 348A and 348B. Apertures 372A are provided for the passage of heat out of tubular wall 344 generated by LED array 366. Disks 368 are spaced apart at equal distances and are in parallel alignment. The inner side of tubular wall 344 defines ten equally spaced circular grooves 374 defining parallel circular configurations in which are positioned and held disk rims 370C.

[0351] Although FIGS. 28, 29, and 29A show round circular circuit board disks 368, it can be appreciated by someone skilled in the art to use circuit boards 368 made in shapes other than a circle. Likewise, the shape of the tubular housing 342 holding the individual circuit boards 368 can be made in a similar shape to match the shape of the circuit boards 368.

[0352] FIGS. 29B, 29C, and 29D show simplified electrical arrangements of the array of LEDs shown with at least one LED in a series parallel configuration. Each LED string has an optional resistor in series with the LED.

[0353] In FIG. 30, each LED 362 includes lens portion 376, body portion 378, and base portion 380. Each lens portion 376 is in juxtaposition with the inner surface of tubular wall 344. LED leads 382 and 384 extend out from the base portion 380 of LED 362. LED lead 382 is bent at a 90-degree angle to form LED lead portions 382A and 382B. Likewise, LED lead 384 is also bent at a 90-degree right angle to form LED lead portions 384A and 384B. In FIG. 30, a detailed isolated view of two typically spaced single LEDs 362 shows each LED 362 mounted to disk 368 with LED lead portions 382A and 384A lateral to disk 368 and LED lead portions 382B and 384B transverse to disk 368. Disks 368 are preferably made of rigid G10 epoxy fiberglass circuit board material, but can be made of other circuit board material known in the art. LED lead portions 382B and 384B extend through disk wall 370A of disk 368

to disk wall 370B of disk 368 by means known in the art as plated through hole pads. The LED leads 382 and 384 support LED 362 so that the center line 386 of each LED 362 is perpendicular to center line 346 of tubular wall 344. The pair of LED leads 382 and 384 connected to each LED 362 of LED array 366 extend through each disk 368 from disk wall 370A to disk wall 370B and then to DC positive lead line 404, or to DC negative lead line 406, or to another LED 362 (not shown) in the same LED string 408 by means known in the art as electrical tracks or traces located on the surface of disk wall 370A and/or disk wall 370B of disk 368.

[0354] In FIG. 30A, a special single SMD LED is mounted to the center of disk 368. Each LED 362 includes lens portion 376, body portion 378, and base portion 380. Lens portion 376 allows the light from LED 362 to be emitted in a direction perpendicular to center line 386 of LED 362 and center line 346 of tubular wall 344 with the majority of light from LED 362 passing straight through tubular wall 344. LED leads 382 and 384 extend out from the base portion 380 of LED 362. LED lead 382 is bent at a 90-degree angle to form LED lead portions 382A and 382B. Likewise, LED lead 384 is also bent at a 90-degree right angle to form LED lead portions 384A and 384B. In FIG. 30A, a detailed isolated view of two typically spaced single LEDs 362 shows each LED 362 mounted to disk 368 with LED lead portions 382A and 384A transverse to disk 368 and LED lead portions 382B and 384B lateral to disk 368. Disks 368 are preferably made of rigid G10 epoxy fiberglass circuit board material, but can be made of other circuit board material known in the art. LED lead portions 382B and 384B rest on and are attached to disk wall 370A of disk 368 with solder to means known in the art as solder pads. The LED leads 382 and 384 support LED 362 so that the center line 386 of each LED 362 is parallel to center line 346 of tubular wall 344. The pair of LED leads 382 and 384 connected to each LED 362 of LED array 366 is then connected to DC positive lead line 404, or to DC negative lead line 406, or to another LED 362 (not shown) in the same LED string 408 by means known in the art as electrical tracks, plated through holes, vias, or traces located on the surface of disk wall 370A and/or disk wall 370B of disk 368. A heat sink 396 is attached to the base portion 380 of each LED 362 to sufficiently extract the heat generated by each LED 362.

[0355] As further indicated in FIGS. 30, 30A, and 30B, six electrical lead lines comprising AC lead line 400, AC lead line 402, DC positive lead line 404, DC negative lead line 406, LED positive lead line 404A, and LED negative lead line 406A are representative of lead lines that extend the entire length of tubular wall 344, in particular extending between and joined to each of the ten disks 368 so as to connect electrically each LED string 408 of each disk 368 as shown in FIG. 34. Each of the lead lines 400, 402, 404, 406, 404A, and 406A are held in position at each of disks 368 by six pins 388A, 388B, 388C, 388D, 388E, and 388F that extend through disks 368 and are in turn held in position by 6-pin connector 356C mounted to disks 368 shown as disk wall 370B for purposes of exposition. 6-pin connector 356C is mounted to each 6-pin header 358, and another 6-pin connector 356D is mounted to disk wall 370A.

[0356] As shown in the schematic electrical and structural representations of FIG. 31, disks 368 and LED array 366 are positioned between integral electronics circuit board 354A

and **354B** that in turn are electrically connected to ballast assembly **334** by single contact pins **340A** and **340B**, respectively. Single contact pins **340A** and **340B** are mounted to and protrude out from base end caps **352A** and **352B**, respectively, for electrical connection to LED array **366**. Contact pins **340A** and **340B** are soldered directly to integral electronics circuit boards **354A** and **354B**, respectively. In particular, being soldered directly to the integral electronics circuit board **354A** electrically connects pin inner extension **340C** of single-pin contact **340A**. Similarly, being soldered directly to integral electronics circuit board **354B** electrically connects pin inner extension **340D** of connecting pin **340B**. 6-pin connector **356A** is shown positioned between and in electrical connection with integral electronics circuit board **356A** and LED array **366**. 6-pin connector **356B** is shown positioned between and in electrical connection with integral electronics circuit board **354B** and LED array **366**.

[0357] As seen in **FIG. 32**, a schematic of an integral electronics circuit **390A** is mounted on integral electronics circuit board **354A**. Integral electronics circuit **390A** is in electrical contact with ballast socket contact **338A**, which is shown as providing AC voltage. Integral electronics circuit **390A** includes bridge rectifier **394**, voltage surge absorber **496**, and resettable fuse **498**. Bridge rectifier **394** converts AC voltage to DC voltage. Voltage surge absorber **496** limits the high voltage to a workable voltage within the design voltage capacity of LEDs **362**. The DC voltage circuits indicated as plus (+) and minus (-) lead to and from LED array **366** and are indicated as DC lead line **404** and **406**, respectively. The presence of AC voltage is indicated by an AC wave symbol ~. Each AC voltage could be DC voltage supplied by certain ballast assemblies **334**. In such a case DC voltage would be supplied to LED array **366** even in the presence of bridge rectifier **394**. It is particularly noted that in such a case, voltage surge absorber **496** would remain operative.

[0358] **FIG. 33** shows an integral electronics circuit **390B** printed on integral electronics board **354B** with voltage protected AC lead line **400** by extension from integral electronics circuit **390A**. The AC lead line **400** having passed through voltage surge absorber **496** is a voltage protected circuit and is in electrical contact with ballast socket contact **338B**. Integral circuit **390B** includes DC positive and DC negative lead lines **404** and **406**, respectively, from LED array **366** to positive and negative DC terminals **438** and **440**, respectively, printed on integral electronics board **354B**. Integral circuit **390B** further includes bypass AC lead line **402** from integral electronics circuit **390A** to ballast socket contact **338B**.

[0359] Circuitry for LED array **366** with integral electronics circuits **390A** and **390B** as connected to the ballast circuitry of ballast assembly **334** is analogous to that shown previously herein in **FIG. 4**. As seen therein and as indicated in **FIG. 29**, the circuitry for LED array **366** includes ten electrical strings in electrical parallel relationship. The ten electrical strings are typified and represented in **FIG. 34** by LED electrical string **408** mounted to disk **368** at one of the disk walls **370A** or **370B**, shown as disk wall **370A** in **FIG. 30** for purposes of exposition only. A single LED row **360** comprises ten LEDs **362** that are electrically connected at equal intervals along each string **408** that is configured in a circular pattern spaced from and concentric with disk rim **370C**. A typical LED string **408** is shown in **FIG. 34** as

including an LED row **360** comprising ten LEDs **364A**, **364B**, **364C**, **364D**, **364E**, **364F**, **364G**, **364H**, **364I**, and **364J**. First and last LEDs **364A** and **364J**, respectively, of LED string **408** generally terminate at the 6-pin connectors shown in **FIG. 30** as typical 6-pin connectors **356C** and **356D** and in **FIG. 34** as typical 6-pin connector **356D**. In particular, the anode side of typical LED **364A** is connected to DC positive lead line **404** by way of LED positive lead line **404A** with optional resistor **392** connected in series between the anode side of LED **364A** connected to LED positive lead line **404A** and DC positive lead line **404**. The cathode side of typical LED **364J** is connected to DC negative lead line **406** by way of LED negative lead line **406A**. Both AC lead line **400** and AC lead line **402** are shown in **FIGS. 32-34**. **FIG. 30B** shows an isolated top view of AC leads **400** and **402**, of positive and negative DC leads **404** and **406**, and of positive and negative LED leads **404A** and **406A**, respectively, extending between disks **368**.

[0360] Analogous to the circuit shown previously herein in **FIG. 4A**, for more than ten LEDs **362** connected in series within each LED electrical string **408**, the LEDs **362** from one disk **368** will extend to the adjacent disk **368**, etc. until all twenty LEDs **362** in LED electrical string **408** spread over two disks **368** are electrically connected into one single series connection. Circuitry for LED array **366** with integral electronics circuits **390A** and **390B** as connected to the ballast circuitry of ballast assembly **334** is also analogous to that shown previously herein in **FIG. 4**. As seen therein and as indicated in **FIG. 29**, the circuitry for LED array **366** includes ten electrical strings in electrical parallel relationship. The ten electrical strings are typified and represented in **FIG. 34** by LED electrical string **408** mounted to disk **368** at one of the disk walls **370A** or **370B**, shown as disk wall **370A** in **FIG. 30** for purposes of exposition only. Each LED row **360** comprises ten LEDs **362** that are electrically connected at equal intervals along each string **408** that is configured in a circular pattern spaced from and concentric with disk rim **370C**. A typical LED string **408** is shown in **FIG. 34** as including an LED row **360** comprising ten LEDs **364A**, **364B**, **364C**, **364D**, **364E**, **364F**, **364G**, **364H**, **364I**, and **364J**. First and last LEDs **364A** and **364J**, respectively, of LED string **408** generally terminate at the 6-pin connectors shown in **FIG. 30** as typical 6-pin connectors **356C** and **356D** and in **FIG. 34** as typical 6-pin connector **356D**. In particular, the anode side of typical LED **364A** is connected to DC positive lead line **404** by way of LED positive lead line **404A** with an optional resistor **392** connected in series between the anode side of LED **364A** connected to LED positive lead line **404A** and DC positive lead line **404**. The cathode side of typical LED **364J** is now connected to anode side of typical LED **364A** of the adjacent LED string **408** of the adjacent disk **368**. The cathode side of typical LED **364J** of the adjacent LED string **408** of the adjacent disk **368** is connected to DC negative lead line **406** by way of LED negative lead line **406A**. This completes the connection of the first twenty LEDs **362** in LED array **366**. The next twenty LEDs **362** and so forth, continue to be connected in a similar manner as described. Both AC lead line **400** and AC lead line **402** are shown in **FIGS. 32-34**. **FIG. 30B** shows an isolated top view of AC leads **400** and **402**, of positive and negative DC leads **404** and **406**, and of positive and negative LED leads **404A** and **406A**, respectively, extending between disks **368**.

[0361] Now analogous to the circuit shown previously herein in FIG. 4B, for forty LEDs 362 all connected in series within one LED electrical string 408, a single LED 362 from one disk 368 will extend to the adjacent single LED 362 in adjacent disk 368, etc. until all forty LEDs 362 in LED electrical string 408 are electrically connected to form one single series connection. Circuitry for LED array 366 with integral electronics circuits 390A and 390B as connected to the ballast circuitry of ballast assembly 334 is also analogous to that shown previously herein in FIG. 4. As seen therein and as indicated in FIG. 29A, the circuitry for LED array 366 includes forty electrical strings in electrical parallel relationship. The forty electrical strings are typified and represented in FIG. 34A by LED electrical string 408 mounted to disk 368 at one of the disk walls 370A or 370B, shown as disk wall 370A in FIG. 30A for purposes of exposition only. Each LED row 360 comprises a single LED 362 that is centrally mounted and concentric with disk rim 370C. Central circular aperture 372 is no longer needed. Instead, vent holes 372A are provided around the periphery of disk 368 for proper cooling of entire LED array 366 and LED retrofit lamp 328. A typical LED string 408 is shown in FIG. 34A as including a single LED row 360 comprising single LED 364A. Each LED 364A of LED string 408 in each disk 368, generally terminate at the 6-pin connectors shown in FIG. 30 as typical 6-pin connectors 356C and 356D and in FIG. 34A as typical 6-pin connector 356D. In particular, the anode side of typical LED 364A is connected to DC positive lead line 404 by way of LED positive lead line 404A with an optional resistor 392 connected in series between the anode side of LED 364A connected to LED positive lead line 404A and DC positive lead line 404. The cathode side of typical LED 364A, which is connected to LED negative lead line 406A, is now connected to the anode side of typical LED 364A of the adjacent LED string 408 of the adjacent disk 368. The cathode side of typical LED 364A of the adjacent LED string 408 of the adjacent disk 368 is likewise connected to LED negative lead line 406A of the adjacent disk 368 and to the anode side of the next typical LED 364A of the adjacent LED string 408 of the adjacent disk 368 and so forth. The next thirty-eight LEDs 364A continue to be connected in a similar manner as described with the cathode of the last and fortieth LED 364A connected to DC negative lead line 406 by way of LED negative lead line 406A. This completes the connection of all forty LEDs 362 in LED array 366. Both AC lead line 400 and AC lead line 402 are shown in FIGS. 32-34. FIG. 30B shows an isolated top view of AC leads 400 and 402, of positive and negative DC leads 404 and 406, and of positive and negative LED leads 404A and 406A, respectively, extending between disks 368.

[0362] The single series string 408 of LEDs 362 as described works ideally with the high-brightness high flux white LEDs available from Lumileds and Nichia in the SMD (surface mounted device) packages discussed previously. Since these new devices require more current to drive them and run on low voltages, the high current available from existing fluorescent ballast outputs with current outputs of 300 mA and higher, along with their characteristically higher voltage outputs provide the perfect match for the present invention. The LEDs 362 have to be connected in series, so that each LED 362 within the same single string 408 will see the same current and therefore output the same brightness. The total voltage required by all the LEDs 362 within the

same single string 408 is equal to the sum of all the individual voltage drops across each LED 362 and should be less than the maximum voltage output of ballast assembly 334.

[0363] FIG. 35 shows an isolated view of one of the base end caps shown for purposes of exposition as base end cap 352A, which is the same as base end cap 352B, mutatis mutandis. Single-pin contact 340A extends directly through the center of base end cap 352A in the longitudinal direction in alignment with center line 346 of tubular wall 344. Single-pin 340A as also shown in FIG. 26 where single-pin contact 340A is mounted into ballast socket 338A. Single-pin contact 340A also includes pin extension 340D that is outwardly positioned from base end cap 352A in the direction towards tubular wall 344. Base end cap 352A is a solid cylinder in configuration as seen in FIGS. 35 and 35A and forms an outer cylindrical wall 410 that is concentric with center line 346 of tubular wall 344 and has opposed flat end walls 412A and 412B that are perpendicular to center line 346. Two cylindrical parallel vent holes 414A and 414B are defined between end walls 412A and 412B spaced directly above and below and lateral to single-pin contact 340A. Single-pin contact 340A includes external side pin extension 340C and internal side pin extension 340D that each extend outwardly positioned from opposed flat end walls 412A and 412B, respectively, for electrical connection with ballast socket contact 338A and with integral electronics circuit board 354A. Analogous external and internal pin extensions 340E and 340F for contact pin 340B likewise exist for electrical connections with ballast socket contact 338B and with integral electronics circuit board 354B.

[0364] As also seen in FIG. 35A, base end cap 352A defines a circular slot 416 that is concentric with center line 346 of tubular wall 344 and concentric with and aligned proximate to circular wall 410. Circular slot 416 is spaced from cylindrical wall 410 at a convenient distance. Circular slot 416 is of such a width and circular end 348A of tubular wall 344 is of such a thickness that circular end 348A is fitted into circular slot 416 and is thus supported by circular slot 416. Base end cap 352B (not shown in detail) defines another circular slot (not shown) analogous to circular slot 416 that is likewise concentric with center line 346 of tubular wall 344 so that circular end 348B of tubular wall 344 can be fitted into the analogous circular slot of base end cap 352B wherein circular end 348B is also supported. In this manner tubular wall 344 is mounted to end caps 352A and 352B. Circular ends 348A and 348B of tubular wall 344 are optionally glued to circular slot 416 of base end cap 352A and the analogous circular slot of base end cap 352B.

[0365] FIGS. 36-45A show another embodiment of the present invention, in particular an LED lamp 418 seen in FIG. 36 retrofitted to an existing fluorescent fixture 420 mounted to a ceiling 422. An electronic instant start type ballast assembly 424, which can also be a hybrid or a magnetic ballast assembly, is positioned within the upper portion of fixture 420. Fixture 420 further includes a pair of fixture mounting portions 426A and 426B extending downwardly from the ends of fixture 420 that include ballast electrical contacts shown as ballast end sockets 428A and 428B that are in electrical contact with ballast assembly 424. Fixture sockets 428A and 428B are each double contact sockets in accordance with the electrical operational requirement of an electronic instant start, hybrid, or magnetic

ballast. As also seen in FIG. 36A, LED lamp 418 includes opposed bi-pin electrical contacts 430A and 430B that are positioned in ballast sockets 428A and 428B, respectively, so that LED lamp 418 is in electrical contact with ballast assembly 424.

[0366] As shown in the disassembled mode of FIG. 37, LED lamp 418 includes an elongated housing 432 particularly configured as a linear tubular wall 434 circular in cross-section taken transverse to a center line 436 that is made of a translucent material such as plastic or glass and preferably having a diffused coating. Tubular wall 434 has opposed tubular wall ends 438A and 438B. LED lamp 418 further includes a pair of opposed lamp base end caps 440A and 440B mounted to bi-pin electrical contacts 430A and 430B, respectively for insertion in ballast electrical socket contacts 428A and 428B in electrical power connection to ballast assembly 424 so as to provide power to LED lamp 418. Tubular wall 434 is mounted to opposed base end caps 440A and 440B at tubular wall ends 438A and 438B in the assembled mode as shown in FIG. 36. An integral electronics circuit board 442A is positioned between base end cap 440A and tubular wall end 438A and an integral electronics circuit board 442B is positioned between base end cap 440B and tubular wall end 438B.

[0367] As seen in FIGS. 37 and 38, LED lamp 418 also includes a 6-pin connector 444A connected to integral electronics circuit board 442A and to a 6-pin header 446 on first disk 454. LED lamp 418 also includes a 6-pin connector 444B connected to integral electronics circuit board 442B and to a 6-pin header 446 on last disk 454.

[0368] For the purposes of exposition, only ten of the original fifteen parallel electrical strings are displayed and described herein. In particular, a sectional view taken through FIG. 37 is shown in FIG. 38 showing a typical single LED row 448 that include ten individual LEDs 450. LED lamp 418 includes ten LED rows 448 that comprise an LED array 452. FIG. 39 shows a partial view that includes each of the ten LED rows 448. LED row 448 includes ten LEDs 450 and is circular in configuration, which is representative of each of the ten LED rows 448 of LED array 452 with all LED rows 448 being aligned in parallel relationship.

[0369] In FIGS. 39 and 40, ten circular disks 454 having opposed flat disk walls 454A and 454B and disk circular rims 454C are positioned and held in tubular wall 434 between tubular end walls 438A and 438B. Each disk 454 that is centrally aligned with center line 436 of tubular wall 434 defines a central circular aperture 456. Apertures 456 are provided for the passage of heat out of tubular wall 434 generated by LED array 452. Disks 454 are spaced apart at equal distances and are in parallel alignment. The inner side of tubular wall 434 defines ten equally spaced circular grooves 458 defining parallel circular configurations in which are positioned and held disk rims 454C.

[0370] Similar to FIG. 39, FIG. 39A now shows a single LED row 448 that includes one individual LED 450. LED lamp 418 includes ten LED rows 448 that can comprise LED array 452. FIG. 39A shows a single LED 450 of each of the ten LED rows 448 mounted in the center of each disk 454. A heat sink 479 is attached to each LED 450 to extract heat away from LED 450. Ten circular disks 454 each having opposed flat disk walls 454A and 454B and disk circular rims 454C are positioned and held in tubular wall 434

between tubular end walls 438A and 438B. Apertures 457 are provided for the passage of heat out of tubular wall 434 generated by LED array 452. Disks 454 are spaced apart at equal distances and are in parallel alignment. The inner side of tubular wall 434 defines ten equally spaced circular grooves 458 defining parallel circular configurations in which are positioned and held disk rims 454C.

[0371] Although FIGS. 39, 39A, and 40 show round circuit board disks 454, it can be appreciated by someone skilled in the art to use circuit boards 454 made in shapes other than a circle. Likewise the shape of the tubular housing 432 holding the individual circuit boards 454 can be made in a similar shape to match the shape of the circuit boards 454.

[0372] FIGS. 39B, 39C, and 39D show simplified electrical arrangements of the array of LEDs shown with at least one LED in a series parallel configuration. Each LED string has an optional resistor in series with the LED.

[0373] In FIG. 40, each LED 450 includes lens portion 460, body portion 462, and base portion 464. Each lens portion 460 is in juxtaposition with the inner surface of tubular wall 434. LED leads 466 and 470 extend out from the base portion 464 of LED 450. LED lead 466 is bent at a 90-degree angle to form LED lead portions 466A and 466B. Likewise, LED lead 470 is also bent at a 90-degree right angle to form LED lead portions 470A and 470B. In FIG. 40, a detailed isolated view of two typically spaced single LEDs shows each LED 450 mounted to disk 454 with LED lead portions 466A and 470A lateral to disk 454 and LED lead portions 466B and 470B transverse to disk 454. Disks 454 are preferably made of rigid G10 epoxy fiberglass circuit board material, but can be made of other circuit board material known in the art. LED lead portions 466B and 470B extend through disk wall 454A of disk 454 to disk wall 454B of disk 454 by means known in the art as plated through hole pads. The LED leads 466 and 470 are secured to disk 454 with solder or other means known in the art. The LED leads 466 and 470 support LED 450 so that the center line 468 of each LED 450 is perpendicular to center line 436 of tubular wall 434. The pair of LED leads 466 and 470 connected to each LED 450 of LED array 452 extend through each disk 454 from disk wall 454A to disk wall 454B and then to DC positive lead line 486A, or to DC negative lead line 486B, or to another LED 450 (not shown) in the same LED string 488 by means known in the art as electrical tracks or traces located on the surface of disk wall 454A and/or disk wall 454B of disk 454.

[0374] In FIG. 40A, a special single SMD LED 450 is mounted to the center of disk 454. Each LED 450 includes lens portion 460, body portion 462, and base portion 464. Lens portion 460 allows the light from LED 450 to be emitted in a direction perpendicular to center line 468 of LED 450 and center line 436 of tubular wall 434 with the majority of light from LED 450 passing straight through tubular wall 434. LED leads 466 and 470 extend out from the base portion 464 of LED 450. LED lead 466 is bent at a 90-degree angle to form LED lead portions 466A and 466B. Likewise, LED lead 470 is also bent at a 90-degree right angle to form LED lead portions 470A and 470B. In FIG. 40A, a detailed isolated view of two typically spaced single LEDs 450 shows each LED 450 mounted to disk 454 with LED lead portions 466A and 470A transverse to disk

454 and LED lead portions **466B** and **470B** lateral to disk **454**. Disks **454** are preferably made of rigid G10 epoxy fiberglass circuit board material, but can be made of other circuit board material known in the art. LED lead portions **466B** and **470B** rest on and are attached to disk wall **454A** of disk **454** with solder to means known in the art as plated through hole pads. The LED leads **466** and **470** support LED **450** so that the center line **468** of each LED **450** is parallel to center line **436** of tubular wall **434**. The pair of LED leads **466** and **470** connected to each LED **450** of LED array **452** is then connected to DC positive lead line **486A**, or to DC negative lead line **486B**, or to another LED **450** (not shown) in the same LED string **488** by means known in the art as electrical tracks or traces located on the surface of disk wall **454A** and/or disk wall **454B** of disk **454**. A heat sink **479** is attached to the base portion **464** of each LED **450** to sufficiently extract the heat generated by each LED **450**.

[0375] As further indicated in **FIGS. 40, 40A, and 40B**, six electrical lead lines comprising AC lead line **484A**, AC lead line **484B**, DC positive lead line **486A**, DC negative lead line **486B**, LED positive lead line **486C**, and LED negative lead line **486D** are representative of lead lines that extend the entire length of tubular wall **434**, in particular extending between and joined to each of the ten disks **454** so as to connect electrically each LED string **488** of each disk **454** as shown in **FIG. 44**. Each of the lead lines **484A, 484B, 486A, 486B, 486C, and 486D** are held in position at each of disks **454** by six pins **474A, 474B, 474C, 474D, 474E, and 474F** that extend through disks **454** and are in turn held in position by 6-pin headers **446** mounted to disks **454** shown as disk wall **454B** for purposes of exposition. A 6-pin connector **444C** is mounted to each 6-pin header **446** and another 6-pin connector **444D** is mounted to disk wall **454A**.

[0376] As shown in the schematic electrical and structural representations of **FIG. 41**, disks **454** and LED array **452** are positioned between integral electronics circuit boards **442A** and **442B** that in turn are electrically connected to ballast assembly **424** by bi-pin contacts **430A** and **430B**, respectively. Bi-pin contacts **430A** and **430B** are mounted to and protrude out from base end caps **440A** and **440B**, respectively, for electrical connection to ballast assembly **424**. Bi-pin contacts **430A** and **430B** are soldered directly to integral electronics circuit boards **442A** and **442B**, respectively. In particular, bi-pin inner extensions **430C** of bi-pin contacts being soldered directly to the integral electronics circuit board **442A** electrically connects **430A**. Also, being soldered directly to integral electronics circuit board **442B** electrically connects bi-pin inner extensions **430D** of bi-pins **430B**. 6-pin connector **444A** is shown positioned between and in electrical connection with integral electronics circuit board **442A** and LED array **452** and disks **454**. 6-pin connector **444B** is shown positioned between and in electrical connection with integral electronics circuit board **442B** and LED array **452** and disks **454**.

[0377] **FIG. 42** shows a schematic of integral electronics circuit **476A** mounted on integral electronics circuit board **442A**. Integral electronics circuit **476A** is also indicated in part in **FIG. 41** as connected to LED array **452**. Integral electronics circuit **476A** is in electrical contact with bi-pin contacts **430A**, which are shown as providing either AC or DC voltage. Integral electronics circuit **476A** includes a bridge rectifier **478A**, voltage surge absorbers **480A** and **480B**, and a resettable fuse **482**. Integral electronic circuit

476A leads to or from LED array **452**. **FIG. 42** indicates the presence of possible AC voltage (rather than possible DC voltage) by an AC wave symbol ~. The AC voltage could be DC voltage supplied by certain ballast assemblies **424** as mentioned earlier herein. In such a case DC voltage would be supplied to LED array **452** even in the presence of bridge rectifier **478A**. It is particularly noted that in such a case, voltage surge absorbers **480A** and **480B** would remain operative. AC lead lines **484A** and **484B** are in a power connection with ballast assembly **424**. DC lead lines **486A** and **486B** are in positive and negative, respectively, direct current voltage relationship with LED array **452**. Bridge rectifier **478A** is in electrical connection with four lead lines **484A, 484B, 486A** and **486B**. Voltage surge absorber **480B** is in electrical contact with AC lead line **484A**. DC lead lines **486A** and **486B** are in electrical contact with bridge rectifier **478A** and in power connection with LED array **452**. Fuse **482** is positioned on DC lead line **486A** between bridge rectifier **478A** and LED array **452**.

[0378] **FIG. 43** shows a schematic of integral electronics circuit **476B** mounted on integral electronics circuit board **442B**. Integral electronics circuit **476B** is also indicated in part in **FIG. 41** as connected to LED array **452**. Integral electronics circuit **476B** is a close mirror image of electronics circuit **476A** mutatis mutandis. Integral electronics circuit **476B** is in electrical contact with bi-pin contacts **430B**, which provide either AC or DC voltage. Integral electronics circuit **476B** includes bridge rectifier **478B** and voltage surge absorbers **480C** and **480D**. Integral electronic circuit **476B** leads to or from LED array **452**. **FIG. 43** indicates the presence of possible AC voltage (rather than possible DC voltage) by an AC wave symbol ~. The AC voltage could be DC voltage supplied by certain ballast assemblies **424** as mentioned earlier herein. In such a case DC voltage would be supplied to LED array **452** even in the presence of bridge rectifier **478B**. It is particularly noted that in such a case, voltage surge absorbers **480C** and **480D** would remain operative. AC lead lines **484A** and **484B** are in a power connection with ballast assembly **424**. DC lead lines **486A** and **486B** are in positive and negative direct current voltage relationship with LED array **452**. Bridge rectifier **478B** is in electrical connection with the four lead lines **484A, 484B, 486A** and **486B**. Lead lines **484A, 484B, 486A, and 486B** are in electrical contact with bridge rectifier **478B** and in power connection with LED array **452**.

[0379] Circuitry for LED array **452** with integral electronics circuits **442A** and **442B** as connected to the ballast circuitry of ballast assembly **424** is analogous to that shown previously herein in **FIG. 4**. As seen therein and as indicated in **FIG. 39**, the circuitry for LED array **452** includes ten electrical strings in electrical parallel relationship. The ten electrical strings are typified and represented in **FIG. 44** by LED electrical string **488** mounted to disk **454** at one of the disk walls **454A** or **454B**, shown as disk wall **454A** in **FIG. 40** for purposes of exposition only. A single LED row **448** comprises ten LEDs **450** that are electrically connected at equal intervals along each string **488** that is configured in a circular pattern spaced from and concentric with disk rim **454C**. A typical LED string **488** is shown in **FIG. 44** as including an LED row **448** comprising ten LEDs **450A, 450B, 450C, 450D, 450E, 450F, 450G, 450H, 450I, and 450J**. First and last LEDs **450A** and **450J**, respectively, of LED string **488** generally terminate at the 6-pin connectors shown in **FIG. 40** as typical 6-pin connectors **444C** and

444D and in FIG. 44 as typical 6-pin connector 444D. In particular, the anode side of typical LED 450A is connected to DC positive lead line 486A by way of LED positive lead line 486C with optional resistor 490 connected in series between the anode side of LED 450A connected to LED positive lead line 486C and DC positive lead line 486A. The cathode side of typical LED 450J is connected to DC negative lead line 486B by way of LED negative lead line 486D. Both AC lead line 484A and AC lead line 484B are shown in FIGS. 42-44. FIG. 40B shows an isolated top view of AC leads 484A and 484B, of positive and negative DC leads 486A and 486B, and of positive and negative LED leads 486C and 486D, respectively, extending between disks 454.

[0380] Analogous to the circuit shown previously herein in FIG. 4A, for more than ten LEDs 450 connected in series within each LED electrical string 488, the LEDs 450 from one disk 454 will extend to the adjacent disk 454, etc. until all twenty LEDs 450 in LED electrical string 488 spread over two disks 454 are electrically connected into one single series connection. Circuitry for LED array 452 with integral electronics circuits 442A and 442B as connected to the ballast circuitry of ballast assembly 424 is also analogous to that shown previously herein in FIG. 4. As seen therein and as indicated in FIG. 39, the circuitry for LED array 452 includes ten electrical strings in electrical parallel relationship. The ten electrical strings are typified and represented in FIG. 44 by LED electrical string 488 mounted to disk 454 at one of the disk walls 454A or 454B, shown as disk wall 454A in FIG. 40 for purposes of exposition only. Each LED row 448 comprises ten LEDs 450 that are electrically connected at equal intervals along each string 488 that is configured in a circular pattern spaced from and concentric with disk rim 454C. A typical LED string 488 is shown in FIG. 44 as including an LED row 448 comprising ten LEDs 450A, 450B, 450C, 450D, 450E, 450F, 450G, 450H, 450I, and 450J. First and last LEDs 450A and 450J, respectively, of LED string 488 generally terminate at the 6-pin connectors shown in FIG. 40 as typical 6-pin connectors 444C and 444D and in FIG. 44 as typical 6-pin connector 444D. In particular, the anode side of typical LED 450A is connected to DC positive lead line 486A by way of LED positive lead line 486C with an optional resistor 490 connected in series between the anode side of LED 450A connected to LED positive lead line 486C and DC positive lead line 486A. The cathode side of typical LED 450J is now connected to anode side of typical LED 450A of the adjacent LED string 488 of the adjacent disk 454. The cathode side of typical LED 450J of the adjacent LED string 488 of the adjacent disk 454 is connected to DC negative lead line 486B by way of LED negative lead line 486D. This completes the connection of the first twenty LEDs 450 in LED array 452. The next twenty LEDs 450 and so forth, continue to be connected in a similar manner as described. Both AC lead line 484A and AC lead line 484B are shown in FIGS. 42-44. FIG. 40B shows an isolated top view of AC leads 484A and 484B, of positive and negative DC leads 486A and 486B, and of positive and negative LED leads 486C and 486D, respectively, extending between disks 454.

[0381] Now analogous to the circuit shown previously herein in FIG. 4B, for forty LEDs 450 all connected in series within one LED electrical string 488, a single LED 450 from one disk 454 will extend to the adjacent single LED 450 in adjacent disk 454, etc. until all forty LEDs 450 in LED

electrical string 488 are electrically connected to form one single series connection. Circuitry for LED array 452 with integral electronics circuits 442A and 442B as connected to the ballast circuitry of ballast assembly 424 is also analogous to that shown previously herein in FIG. 4. As seen therein and as indicated in FIG. 39A, the circuitry for LED array 452 includes forty electrical strings in electrical parallel relationship. The forty electrical strings are typified and represented in FIG. 44A by LED electrical string 488 mounted to disk 454 at one of the disk walls 454A or 454B, shown as disk wall 454A in FIG. 40A for purposes of exposition only. Each LED row 448 comprises a single LED 450 that is centrally mounted and concentric with disk rim 454C. Central circular aperture 456 is no longer needed. Instead, vent holes 457 are provided around the periphery of disk 454 for proper cooling of entire LED array 452 and LED retrofit lamp 418. A typical LED string 488 is shown in FIG. 44A as including a single LED row 448 comprising single LED 450A. Each LED 450A of LED string 488 in each disk 454, generally terminate at the 6-pin connectors shown in FIG. 40 as typical 6-pin connectors 444C and 444D and in FIG. 44A as typical 6-pin connector 444D. In particular, the anode side of typical LED 450A is connected to DC positive lead line 486A by way of LED positive lead line 486C with an optional resistor 490 connected in series between the anode side of LED 450A connected to LED positive lead line 486C and DC positive lead line 486A. The cathode side of typical LED 450A, which is connected to LED negative lead line 486D, is now connected to the anode side of typical LED 450A of the adjacent LED string 488 of the adjacent disk 454. The cathode side of typical LED 450A of the adjacent LED string 488 of the adjacent disk 454 is likewise connected to LED negative lead line 486D of the adjacent disk 454 and to the anode side of the next typical LED 450A of the adjacent LED string 488 of the adjacent disk 454 and so forth. The next thirty-eight LEDs 450A continue to be connected in a similar manner as described with the cathode of the last and fortieth LED 450A connected to DC negative lead line 486B by way of LED negative lead line 486D. This completes the connection of all forty LEDs 450 in LED array 452. Both AC lead line 484A and AC lead line 484B are shown in FIGS. 42-44. FIG. 40B shows an isolated top view of AC leads 484A and 484B, of positive and negative DC leads 486A and 486B, and of positive and negative LED leads 486C and 486D, respectively, extending between disks 454.

[0382] The single series string 488 of LEDs 450 as described works ideally with the high-brightness high flux white LEDs available from Lumileds and Nichia in the SMD packages. Since these new devices require more current to drive them and run on low voltages, the high current available from existing fluorescent ballast outputs with current outputs of 300 mA and higher, along with their characteristically higher voltage outputs provide the perfect match for the present invention. The LEDs 450 have to be connected in series, so that each LED 450 within the same single string 488 will see the same current and therefore output the same brightness. The total voltage required by all the LEDs 450 within the same single string 488 is equal to the sum of all the individual voltage drops across each LED 450 and should be less than the maximum voltage output of ballast assembly 424.

[0383] FIG. 45 shows an isolated top view of one of the base end caps, namely, base end cap 440A, which is analo-

gous to base end cap 440B, mutatis mutandis. Bi-pin electrical contacts 430A extend directly through base end cap 440A in the longitudinal direction in alignment with center line 436 of tubular wall 434 with bi-pin internal extensions 430C shown. Base end cap 440A is a solid cylinder in configuration as seen in FIGS. 45 and 45A and forms an outer cylindrical wall 492 that is concentric with center line 436 of tubular wall 434 and has opposed flat end walls 494A and 494B that are perpendicular to center line 436. Two cylindrical vent holes 496A and 496B are defined between end walls 494A and 494B in vertical alignment with center line 436.

[0384] As also seen in FIG. 45A, base end cap 440A defines a circular slot 498 that is concentric with center line 436 of tubular wall 434 and concentric with and aligned proximate to circular wall 492. Outer circular slot 498 is of such a width and circular end 438A of tubular wall 434 is of such a thickness and diameter that outer circular slot 498 accepts circular end 438A into a fitting relationship and circular end 438A is thus supported by circular slot 498. In this similar manner tubular wall 434 is mounted to both end caps 440A and 440B. Circular ends 438A and 438B of tubular wall 434 are optionally glued to circular slot 498 of base end cap 440A and the analogous circular slot of base end cap 440B.

[0385] A portion of a curved tubular wall 500 shown in FIG. 46 includes an inner curved portion 502 and an outer curved portion 504. Disks 506 are shown as six in number for purposes of exposition only and each having six LEDs 508 mounted thereto having rims 510 mounted in slots 512 defined by tubular wall 500. Disks 506 are positioned and held in tubular wall 500 at curved inner portion 502 at first equal intervals and at curved outer portion 504 at second equal intervals with the second equal intervals being greater than the first equal intervals. Curved tubular wall 500 has a curved center line 514. Each LED 508 has an LED center line 516 (seen from top view) such as LED center line 468 seen in FIG. 40 that is aligned with curved center line 514 of curved tubular wall 500 relative to a plane defined by any LED row 528 indicated by arrows in FIG. 46, or relative to a parallel plane defined by disks 506.

[0386] FIG. 47 shows a simplified cross-section of an oval tubular housing 530 as related to FIG. 1 with a self-biased oval circuit board 532 mounted therein.

[0387] FIG. 47A shows a simplified cross-section of a triangular tubular housing 534 as related to FIG. 1 with a self-biased triangular circuit board 536 mounted therein.

[0388] FIG. 47B shows a simplified cross-section of a rectangular tubular housing 538 as related to FIG. 1 with a self-biased rectangular circuit board 540 mounted therein.

[0389] FIG. 47C shows a simplified cross-section of a hexagonal tubular housing 542 as related to FIG. 1 with a self-biased hexagonal circuit board 544 mounted therein.

[0390] FIG. 47D shows a simplified cross-section of an octagonal tubular housing 546 as related to FIG. 1 with a self-biased octagonal circuit board 548 mounted therein.

[0391] FIG. 48 shows a simplified cross-section of an oval tubular housing 550 as related to FIG. 26 with an oval support structure 550A mounted therein.

[0392] FIG. 48A shows a simplified cross-section of a triangular tubular housing 552 as related to FIG. 26 with a triangular support structure 552A mounted therein.

[0393] FIG. 48B shows a simplified cross-section of a rectangular tubular housing 554 as related to FIG. 26 with a rectangular support structure 554A mounted therein.

[0394] FIG. 48C shows a simplified cross-section of a hexagonal tubular housing 556 as related to FIG. 26 with a hexagonal support structure 556A mounted therein.

[0395] FIG. 48D shows a simplified cross-section of an octagonal tubular housing 558 as related to FIG. 26 with an octagonal support structure 558A mounted therein.

[0396] FIG. 49 shows a high-brightness SMD LED 560 having an SMD LED center line 562 mounted to a typical support structure 564 mounted within a tubular housing (not shown) such as tubular housings 550, 552, 554, 556, and 558 and in addition analogous to disks 368 mounted in tubular housing 342 and disks 454 mounted in tubular housing 432. Typical support structure 564 and the tubular housing in which it is mounted have a tubular housing center line 566 that is in alignment with SMD LED center line 562. A light beam 568 shown in phantom line is emitted from high-brightness SMD LED 560 perpendicular to SMD LED center line 562 and tubular housing center line 566 at a 360-degree angle. Light beam 568 is generated in a radial light beam plane that is lateral to and slightly spaced from support structure 564, which is generally flat in configuration in side view. Thus, light beam 568 passes through the particular tubular wall to which support structure 564 is mounted in a 360-degree coverage. High-brightness SMD LED 560 shown can be, for example, a Luxeon Emitter high-brightness LED, but other analogous high-brightness side-emitting radial beam SMD LEDs that emit high flux side-emitting radial light beams can be used. Reference is now made to the drawings and in particular to FIGS. 1-10 in which identical or similar parts are designated by the same reference numerals throughout.

[0397] An LED lamp 570 shown in FIGS. 50-59 is seen in FIG. 50 retrofitted to an existing elongated fluorescent fixture 572 mounted to a ceiling 574. An instant start type ballast assembly 576 is positioned within the upper portion of fixture 572. Fixture 572 further includes a pair of fixture mounting portions 578A and 578B extending downwardly from the ends of fixture 572 that include ballast electrical contacts shown as ballast sockets 580A and 580B that are in electrical contact with ballast assembly 576. Fixture sockets 580A and 580B are each single contact sockets in accordance with the electrical operational requirement of an instant start type ballast. As also seen in FIG. 50A, LED lamp 570 includes opposed single-pin electrical contacts 582A and 582B that are positioned in ballast sockets 580A and 580B respectively, so that LED lamp 570 is in electrical contact with ballast assembly 576.

[0398] As shown in the disassembled mode of FIG. 51 and also indicated schematically in FIG. 53, LED lamp 570 includes an elongated housing 584 particularly configured as a tubular wall 586 circular in cross-section taken transverse to a center line 588 that is made of a translucent material such as plastic or glass and preferably having a diffused coating. Tubular wall 586 has opposed tubular wall ends 590A and 590B with cooling vent holes 589A and 589B

juxtaposed to tubular wall ends **590A** and **590B**. Optional electric micro fans (not shown) can be used to provide forced air-cooling across the electronic components contained within elongated housing **584**. The optional cooling micro fans can be arranged in a push or pull configuration. LED lamp **570** further includes a pair of opposed lamp base end caps **592A** and **592B** mounted to single electrical contact pins **582A** and **582B**, respectively for insertion in ballast electrical sockets **580A** and **580B** in electrical power connection to ballast assembly **576** so as to provide power to LED lamp **570**. Tubular wall **586** is mounted to opposed base end caps **592A** and **592B** at tubular wall ends **590A** and **590B** in the assembled mode as shown in **FIG. 50**. LED lamp **570** also includes electrical LED array circuit boards **594A** and **594B** that are rectangular in configuration. Circuit board **594A** is preferably manufactured from a Metal Core Printed Circuit Board (MCPCB) consisting of a circuit layer **598A**, a dielectric layer **598B**, and a metal base layer **598C**. Likewise, circuit board **594B** comprises a circuit layer **598A**, a dielectric layer **598B**, and metal base layer **598C**. Each dielectric layer **598B** is an electrically non-conductive, but is a thermally conductive dielectric layer separating the top conductive circuit layer **598A** and metal base layer **598C**. Each circuit layer **598A** contains the electronic components including the LEDs, traces, vias, holes, etc. while the metal base layer **598C** is attached to heat sink **596**. Metal core printed circuit boards are designed for attachment to heat sinks using thermal epoxy, Sil-pads, or heat conductive grease **597** used between metal base layer **598C** and heat sink **596**. The metal substrate LED array circuit boards **594A** and **594B** are each screwed down to heat sink **596** with screws (not shown) or other mounting hardware.

[0399] Circuit layer **598A** is the actual printed circuit foil containing the electrical connections including pads, traces, vias, etc. Electronic integrated circuit components get mounted to circuit layer **598A**. Dielectric layer **598B** offers electrical isolation with minimum thermal resistance and bonds the circuit metal layer **598A** to the metal base layer **598C**. Metal base layer **598C** is often aluminum, but other metals such as copper may also be used. The most widely used base material thickness is 0.04" (1.0 mm) in aluminum, although other thicknesses are available. The metal base layer **598C** is further attached to heat sink **596** with thermally conductive grease **597** or other material to extract heat away from the LEDs mounted to circuit layer **598A**. The Berquist Company markets their version of a MCPCB called Thermal Clad (T-Clad). Although this embodiment describes a generally rectangular configuration for circuit boards **594A** and **594B**, it can be appreciated by someone skilled in the art to form circuit boards **594A** and **594B** into curved shapes or combinations of rectangular and curved portions.

[0400] LED array circuit boards **594A** and **594B** are positioned within tubular wall **586** and supported by opposed lamp base end caps **592A** and **592B**. In particular, LED array circuit boards **594A** and **594B** each have opposed circuit board short edge ends **595A** and **595B** that are positioned in association with tubular wall ends **590A** and **590B**, respectively. As mentioned earlier, LED array circuit boards **594A** and **594B** each have a circuit layer **598A**, a dielectric layer **598B**, and a metal base layer **598C** respectively with heat sink **596** sandwiched between metal base layers **598C** between tubular wall circular ends **590A** and **590B**, and circuit layers **598A** being spaced away from

tubular wall **586**. LED array circuit boards **594A** and **594B** are shown in **FIGS. 51** and **52**, and indicated schematically in **FIG. 54**.

[0401] LED lamp **570** further includes an LED array **600** comprising a total of thirty Lumileds Luxeon surface mounted device (SMD) LED emitters **606** mounted to LED array circuit boards **594A** and **594B**. Integral electronics **602A** is positioned on one end of LED array circuit boards **594A** and **594B** in close proximity to base end cap **592A**, and integral electronics **602B** is positioned on the opposite end of LED array circuit boards **594A** and **594B** in close proximity to base end cap **592B**. As seen in **FIGS. 51** and **54**, integral electronics **602A** is connected to LED array circuit boards **594A** and **594B** and also to integral electronics **602B**. Integral electronics **602A** and **602B** are identical in both LED array circuit boards **594A** and **594B**.

[0402] The sectional view of **FIG. 52** includes a single typical SMD LED **606** from each LED array **600** in LED array circuit boards **594A** and **594B** shown in **FIG. 53**. LED **606** is representative of one of the fifteen LEDs **606** connected in series in each LED array **600** as shown in **FIG. 53**. Each LED **606** includes a light emitting lens portion **608**, a body portion **610**, and a base portion **612**. A cylindrical space **614** is defined between circuit layer **598A** of each LED array circuit board **594A** and **594B** and cylindrical tubular wall **586**. Each LED **606** is positioned in space **614** as seen in the detailed view of **FIG. 52A**. Lens portion **608** is in juxtaposition with the inner surface of tubular wall **586** and base portion **612** is mounted to metal base layer **598C** of LED array circuit boards **594A** and **594B**. A detailed view of a single LED **606** in **FIG. 52A** shows a rigid LED electrical lead **616** extending from LED base portion **612** to LED array circuit boards **594A** and **594B** for electrical connection therewith. Lead **616** is secured to LED circuit boards **594A** and **594B** by solder **618**. An LED center line **620** is aligned transverse to center line **588** of tubular wall **586**. As shown in the sectional view of **FIG. 52**, light is emitted through tubular wall **586** by the two SMD LEDs **606** in substantially equal strength about the entire circumference of tubular wall **586**. Projection of this arrangement is such that all fifteen LEDs **606** are likewise arranged to emit light rays in substantially equal strength the entire length of tubular wall **586** and in substantially equal strength about the entire 360-degree circumference of tubular wall **586**. The distance between LED center line **620** and LED array circuit boards **594A** and **594B** is the shortest that is geometrically possible with heat sink **596** sandwiched between LED array circuit boards **594A** and **594B**. In **FIG. 52A**, LED center line **620** is perpendicular to tubular wall center line **588**. **FIG. 52A** indicates a tangential plane **622** relative to the cylindrical inner surface of linear wall **586** in phantom line at the apex of LED lens portion **608** that is perpendicular to LED center line **620** so that all LEDs **606** emit light through tubular wall **586** in a direction perpendicular to tangential plane **622**, so that maximum illumination is obtained from all SMD LEDs **606**.

[0403] **FIG. 53** shows the total LED electrical circuitry for LED lamp **570**. The LED electrical circuitry for both LED array circuit boards **594A** and **594B** are identically described herein, mutatis mutandis. The total LED circuitry comprises two circuit assemblies, namely, existing ballast assembly circuitry **624** and LED circuitry **626**, the latter including LED array circuitry **628** and integral electronics circuitry

640. LED circuitry **626** provides electrical circuits for LED lighting element array **600**. When electrical power, normally 120 VAC or 240 VAC at 50 or 60 Hz, is applied, ballast circuitry **624** as is known in the art of instant start ballasts provides either an AC or DC voltage with a fixed current limit across ballast electrical sockets **580A** and **580B**, which is conducted through LED circuitry **626** by way of single contact pins **582A** and **582B** to a voltage input at a bridge rectifier **630**. Bridge rectifier **630** converts AC voltage to DC voltage if ballast circuitry **624** supplies AC voltage. In such a situation wherein ballast circuitry **624** supplies DC voltage, the voltage remains DC voltage even in the presence of bridge rectifier **630**.

[0404] LEDs **606** have an LED voltage design capacity, and a voltage suppressor **632** is used to protect LED lighting element array **600** and other electronic components primarily including LEDs **606** by limiting the initial high voltage generated by ballast circuitry **624** to a safe and workable voltage.

[0405] Bridge rectifier **630** provides a positive voltage $V+$ to an optional resettable fuse **634** connected to the anode end and also provides current protection to LED array circuitry **628**. Fuse **634** is normally closed and will open and de-energize LED array circuitry **628** only if the current exceeds the allowable current through LED array **600**. The value for resettable fuse **634** should be equal to or be lower than the maximum current limit of ballast assembly **576**. Fuse **634** will reset automatically after a cool-down period.

[0406] Ballast circuitry **624** limits the current going into LED circuitry **626**. This limitation is ideal for the use of LEDs in general and of LED lamp **570** in particular because LEDs are basically current devices regardless of the driving voltage. The actual number of LEDs will vary in accordance with the actual ballast assembly **576** used. In the example of the embodiment herein, ballast assembly **576** provides a maximum current limit of 300 mA, but higher current ratings are also available.

[0407] LED array circuitry **628** includes a single LED string **636** with all SMD LEDs **606** within LED string **636** being electrically wired in series. Each SMD LED **606** is preferably positioned and arranged equidistant from one another in LED string **636**. Each LED array circuitry **628** includes fifteen SMD LEDs **606** electrically mounted in series within LED string **636** for a total of fifteen SMD LEDs **606** that constitute each LED array **600** in LED array circuit boards **594A** and **594B**. SMD LEDs **606** are positioned in equidistant relationship with one another and extend generally the length of tubular wall **586**, that is, generally between tubular wall ends **590A** and **590B**. As shown in FIG. 53, LED string **636** includes an optional resistor **638** in respective series alignment with LED string **636** at the current input. The current limiting resistor **638** is purely optional, because the existing fluorescent ballast used here is already a current limiting device. The resistor **638** then serves as a secondary protection device. A higher number of individual SMD LEDs **606** can be connected in series within each LED string **636**. The maximum number of SMD LEDs **606** being configured around the circumference of the 1.5-inch diameter of tubular wall **586** in the particular example herein of LED lamp **570** is two. Each LED **606** is configured with the anode towards the positive voltage $V+$ and the cathode towards the negative voltage $V-$. When

LED array circuitry **628** is energized, the positive voltage that is applied through resistor **638** to the anode end of LED string **636**, and the negative voltage that is applied to the cathode end of LED string **636** will forward bias LEDs **604** connected within LED string **636** and cause SMD LEDs **606** to turn on and emit light.

[0408] Ballast assembly **576** regulates the electrical current through SMD LEDs **606** to the correct value of 300 mA for each SMD LED **606**. Each LED string **636** sees the total current applied to LED array circuitry **628**. Those skilled in the art will appreciate that different ballasts provide different current outputs to drive LEDs that require higher operating currents. To provide additional current to drive the newer high-flux LEDs that require higher currents to operate, the electronic ballast outputs can be tied together in parallel to "overdrive" the LED retrofit lamp of the present invention.

[0409] The total number of LEDs in series within each LED string **636** is arbitrary since each SMD LED **606** in each LED string **636** will see the same current. The maximum number of LEDs is dependent on the maximum power capacity of the ballast. Again in this example, fifteen SMD LEDs **606** are shown connected in series within each LED string **636**. Each of the fifteen SMD LEDs **606** connected in series within each LED string **636** sees this 300 mA. In accordance with the type of ballast assembly **576** used, when ballast assembly **576** is first energized, a high voltage may be applied momentarily across ballast socket contacts **580A** and **580B**, which conduct to pin contacts **582A** and **582B**. Such high voltage is normally used to help ignite a fluorescent tube and establish conductive phosphor gas, but high voltage is unnecessary for LED array circuitry **628** and voltage surge absorber **632** absorbs the voltage applied by ballast circuitry **624**, so that the initial high voltage supplied is limited to an acceptable level for the circuit. Optional resettable fuse **634** is also shown to provide current protection to LED array circuitry **628**.

[0410] As can be seen from FIG. 53A, there can be more than fifteen 5 mm LEDs **604** connected in series within each string **636A-636O**. There are twenty 5 mm LEDs **604** in this example, but there can be more 5 mm LEDs **604** connected in series within each string **636A-636O**. LED array circuitry **628** includes fifteen electrical LED strings **636** individually designated as strings **636A, 636B, 636C, 636D, 636E, 636F, 636G, 636H, 636I, 636J, 636K, 636L, 636M, 636N** and **636O** all in parallel relationship with all 5 mm LEDs **604** within each string **636A-636O** being electrically wired in series. Parallel strings **636A-636O** are so positioned and arranged that each of the fifteen strings **636** is equidistant from one another. LED array circuitry **628** includes twenty 5 mm LEDs **604** electrically mounted in series within each of the fifteen parallel strings **636A-636O** for a total of three-hundred 5 mm LEDs **604** that constitute each LED array **600**. 5 mm LEDs **604** are positioned in equidistant relationship with one another and extend generally the length of tubular wall **586**, that is, generally between tubular wall ends **590A** and **590B**. As shown in FIG. 53A, each of strings **636A-636O** includes an optional resistor **638** designated individually as resistors **638A, 638B, 638C, 638D, 638E, 638F, 638G, 638H, 638I, 638J, 638K, 638L, 638M, 638N**, and **638O** in respective series alignment with strings **636A-636O** at the current input for a total of fifteen resistors **638**. Again, a higher number of individual 5 mm LEDs **604** can be connected in series within each LED string **636**. Each

5 mm LED **604** is configured with the anode towards the positive voltage $V+$ and the cathode towards the negative voltage $V-$. When LED array circuitry **628** is energized, the positive voltage that is applied through resistors **638A-638O** to the anode end of LED strings **636A-636O**, and the negative voltage that is applied to the cathode end of LED strings **636A-636O** will forward bias 5 mm LEDs **604** connected to LED strings **636A-636O** and cause 5 mm LEDs **604** to turn on and emit light.

[0411] Ballast assembly **576** regulates the electrical current through 5 mm LEDs **604** to the correct value of 20 mA for each 5 mm LED **604**. The fifteen LED strings **636A-636O** equally divide the total current applied to LED array circuitry **628**. Those skilled in the art will appreciate that different ballasts provide different current outputs.

[0412] If the forward drive current for each 5 mm LEDs **604** is known, then the output current of ballast assembly **576** divided by the forward drive current gives the exact number of parallel strings of 5 mm LEDs **604** in the each particular LED array, here LED array **600**. The total number of 5 mm LEDs **604** in series within each LED string **636** is arbitrary since each 5 mm LED **604** in each LED string **636** will see the same current. Again in this example, twenty 5 mm LEDs **604** are shown connected in series within each LED string **636**. Ballast assembly **576** provides 300 mA of current, which when divided by the fifteen LED strings **636** of twenty 5 mm LEDs **604** per LED string **636** gives 20 mA per LED string **636**. Each of the twenty 5 mm LEDs **604** connected in series within each LED string **636** sees this 20 mA. In accordance with the type of ballast assembly **576** used, when ballast assembly **576** is first energized, a high voltage may be applied momentarily across ballast socket contacts **580A** and **580B**, which conduct to pin contacts **582A** and **582B**. Such high voltage is normally used to help ignite a fluorescent tube and establish conductive phosphor gas, but high voltage is unnecessary for LED array circuitry **628** and voltage surge absorber **632** absorbs the voltage applied by ballast circuitry **624**, so that the initial high voltage supplied is limited to an acceptable level for the circuit.

[0413] FIG. 53B shows another alternate arrangement of LED array circuitry **628**. LED array circuitry **628** consists of a single LED string **636** of SMD LEDs **606** arranged in series relationship including for exposition purposes only forty SMD LEDs **606** all electrically connected in series. Positive voltage $V+$ is connected to optional resettable fuse **634**, which in turn is connected to one side of current limiting resistor **638**. The anode of the first LED in the series string is then connected to the other end of resistor **638**. A number other than forty SMD LEDs **606** can be connected within the series LED string **636** to fill up the entire length of the tubular wall of the present invention. The cathode of the first SMD LED **606** in the series LED string **636** is connected to the anode of the second SMD LED **606**, the cathode of the second SMD LED **606** in the series LED string **636** is then connected to the anode of the third SMD LED **606**, and so forth. The cathode of the last SMD LED **606** in the series LED string **636** is likewise connected to ground or the negative potential $V-$. The individual SMD LEDs **606** in the single series LED string **636** are so positioned and arranged such that each of the forty LEDs is spaced equidistant from one another substantially filling the entire length of tubular wall **586**. SMD LEDs **606** are

positioned in equidistant relationship with one another and extend substantially the length of tubular wall **586**, that is, generally between tubular wall ends **590A** and **590B**. As shown in FIG. 53B, the single series LED string **636** includes an optional resistor **638** in respective series alignment with single series LED string **636** at the current input. Each SMD LED **606** is configured with the anode towards the positive voltage $V+$ and the cathode towards the negative voltage $V-$. When LED array circuitry **628** is energized, the positive voltage that is applied through resistor **638** to the anode end of single series LED string **636** and the negative voltage that is applied to the cathode end of single series LED string **636** will forward bias SMD LEDs **606** connected in series within single series LED string **636**, and cause SMD LEDs **606** to turn on and emit light.

[0414] The single series LED string **636** of SMD LEDs **606** as described above works ideally with the high-brightness or brighter high flux white SMD LEDs **606A** available from Lumileds and Nichia in the SMD packages as discussed earlier herein. Since these new devices require more current to drive them and run on low voltages, the high current available from existing fluorescent ballast outputs with current outputs of 300 mA and higher, along with their characteristically higher voltage outputs provide the perfect match for the present invention. The high-brightness SMD LEDs **606A** have to be connected in series, so that each high-brightness SMD LED **606A** within the same single LED string **636** will see the same current and therefore output the same brightness. The total voltage required by all the high-brightness SMD LEDs **606A** within the same single LED string **636** is equal to the sum of all the individual voltage drops across each high-brightness SMD LED **606A** and should be less than the maximum voltage output of ballast assembly **576**.

[0415] FIG. 53C shows a simplified arrangement of the LED array circuitry **628** of SMD LEDs **606** for the overall electrical circuit shown in FIG. 53. AC lead lines **642** and **646** and DC positive lead line **648** and DC negative lead line **650** are connected to integral electronics **602A** and **602B**. Four parallel LED strings **636** each including a resistor **638** are each connected to DC positive lead line **648** on one side, and to LED positive lead line **656** or the anode side of each LED **604** and on the other side. The cathode side of each LED **604** is then connected to LED negative lead line **658** and to DC negative lead line **650** directly. AC lead lines **642** and **646** simply pass through LED array circuitry **628**.

[0416] FIG. 53D shows a simplified arrangement of the LED array circuitry **628** of 5 mm LEDs **604** for the overall electrical circuit shown in FIG. 53A. AC lead lines **642** and **646** and DC positive lead line **648** and DC negative lead line **650** are connected to integral electronics **602A** and **602B**. Two parallel LED strings **636** each including a single resistor **638** are each connected to DC positive lead line **648** on one side, and to LED positive lead line **656** or the anode side of the first 5 mm LED **604** in each LED string **636** on the other side. The cathode side of the first 5 mm LED **604** is connected to LED negative lead line **658** and to adjacent LED positive lead line **656** or the anode side of the second 5 mm LED **604** in the same LED string **636**. The cathode side of the second 5 mm LED **604** is then connected to LED negative lead line **658** and to DC negative lead line **650** directly in the same LED string **636**. AC lead lines **642** and **646** simply pass through LED array circuitry **628**.

[0417] FIG. 53E shows a simplified arrangement of the LED array circuitry 628 of LEDs for the overall electrical circuit shown in FIG. 53B. AC lead lines 642 and 646 and DC positive lead line 648 and DC negative lead line 650 are connected to integral electronics 602A and 602B. Single parallel LED string 636 including a single resistor 638 is connected to DC positive lead line 648 on one side, and to LED positive lead line 656 or the anode side of the first high-brightness SMD LED 606A in the LED string 636 on the other side. The cathode side of the first high-brightness SMD LED 606A is connected to LED negative lead line 658 and to adjacent LED positive lead line 656 or the anode side of the second LED 606A. The cathode side of the second LED 606A is connected to LED negative lead line 658 and to adjacent LED positive lead line 656 or the anode side of the third high-brightness SMD LED 606A. The cathode side of the third high-brightness SMD LED 606A is connected to LED negative lead line 658 and to adjacent LED positive lead line 656 or the anode side of the fourth high-brightness SMD LED 606A. The cathode side of the fourth high-brightness SMD LED 606A is then connected to LED negative lead line 658 and to DC negative lead line 650 directly. AC lead lines 642 and 646 simply pass through LED array circuitry 628.

[0418] The term high-brightness as describing LEDs herein is a relative term. In general, for the purposes of the present application, high-brightness LEDs refer to LEDs that offer the highest luminous flux outputs. Luminous flux is defined as lumens per watt. For example, Lumileds Luxeon high-brightness LEDs produce the highest luminous flux outputs at the present time. Luxeon 5-watt high-brightness LEDs offer extreme luminous density with lumens per package that is four times the output of an earlier Luxeon 1-watt LED and up to 50 times the output of earlier discrete 5 mm LED packages. Gelcore is soon to offer an equivalent and competitive product.

[0419] With the new high-brightness LEDs in mind, FIG. 53F shows a single high-brightness LED 606A positioned on an electrical string in what is defined herein as an electrical series arrangement with single a high-brightness LED 606A for the overall electrical circuit shown in FIG. 53. The single high-brightness LED 606A fulfills a particular lighting requirement formerly fulfilled by a fluorescent lamp.

[0420] Likewise, FIG. 53G shows two high-brightness LEDs 606A in electrical parallel arrangement with one high-brightness LED 606A positioned on each of the two parallel strings for the overall electrical circuit shown in FIG. 53. The two high-brightness LEDs 606A fulfill a particular lighting requirement formerly fulfilled by a fluorescent lamp.

[0421] As shown in the schematic electrical and structural representations of FIG. 54, LED array circuit boards 594A and 594B of LED array 600 is positioned between integral electronics 602A and 602B that in turn are electrically connected to ballast circuitry 624 by single contact pins 582A and 582B, respectively. Single contact pins 582A and 582B are mounted to and protrude out from base end caps 592A and 592B, respectively, for electrical connection to integral electronics 602A and 602B. Contact pins 582A and 582B are soldered directly to integral electronics 602A and 602B, respectively mounted onto LED array circuit boards

594A and 594B. In particular, pin inner extension 582D of connecting pin 582A is electrically connected by being soldered directly to the integral electronics 602A. Similarly, being soldered directly to integral electronics 602B electrically connects pin inner extension 582F of connecting pin 582B. It should be noted that someone skilled in the art could use other means of electrically connecting the contact pins 582A and 582B to LED array circuit boards 594A and 594B. These techniques include the use of connectors and headers, plugs and sockets, receptacles, etc. among many others. Integral electronics 602A is in electrical connection with LED array circuit boards 594A and 594B and LED circuitry 626 mounted thereon as shown in FIG. 53. Likewise, integral electronics 602B is in electrical connection with LED array circuit boards 594A and 594B and LED circuitry 626 mounted thereon.

[0422] As seen in FIG. 55, a schematic of integral electronics circuitry 640 is mounted on integral electronics 602A. Integral electronics circuit 640 is also shown in FIG. 53 as part of the schematically shown LED circuitry 626. Integral electronics circuitry 640 is in electrical contact with ballast socket contact 580A, which is shown as providing AC voltage. Integral electronics circuitry 640 includes bridge rectifier 630, voltage surge absorber 632, and fuse 634. Bridge rectifier 630 converts AC voltage to DC voltage. Voltage surge absorber 632 limits the high voltage to a workable voltage within the design voltage capacity of 5 mm LEDs 604 or SMD LEDs 606. The DC voltage circuits indicated as plus (+) and minus (−) and indicated as DC leads 648 and 650 lead to and from LED array 600 (not shown). It is noted that FIG. 55 indicates the presence of AC voltage by an AC wave symbol ~. Each AC voltage could be DC voltage supplied by certain ballast assemblies 576 as mentioned earlier herein. In such a case DC voltage would be supplied to LED lighting element array 600 even in the presence of bridge rectifier 630. It is particularly noted that in such a case, voltage surge absorber 632 would remain operative.

[0423] FIG. 56 shows a further schematic of integral electronics 602B that includes integral electronics circuitry 644 mounted on integral electronics 602B with voltage protected AC lead line 646 extending from LED array 600 (not shown) and by extension from integral electronics circuitry 640. The AC lead line 646 having passed through voltage surge absorber 632 is a voltage protected circuit and is in electrical contact with ballast socket contact 580B. Integral circuitry 644 includes DC positive and DC negative lead lines 648 and 650, respectively, from LED array circuitry 628 to positive and negative DC terminals 652 and 654, respectively, mounted on integral electronics 602B. Integral circuitry 644 further includes AC lead line 646 from LED array circuitry 628 to ballast socket contact 580B.

[0424] FIGS. 55 and 56 show the lead lines going into and out of LED circuitry 626 respectively. The lead lines include AC lead lines 642 and 646, positive DC voltage 648, DC negative voltage 650, LED positive lead line 656, and LED negative lead line 658. The AC lead lines 642 and 646 are basically feeding through LED circuitry 626, while the positive DC voltage lead line 648 and negative DC voltage lead line 650 are used primarily to power the LED array 600. DC positive lead line 648 is the same as LED positive lead line 656 and DC negative lead line 650 is the same as LED negative lead line 658. LED array circuitry 628 therefore

consists of all electrical components and internal wiring and connections required to provide proper operating voltages and currents to 5 mm LEDs 604 or to SMD LEDs 606 connected in parallel, series, or any combinations of the two.

[0425] FIGS. 57 and 57A show a close-up of elongated linear housing 584 with details of cooling vent holes 589A and 589B located on opposite ends of elongated linear housing 584 in both side and cross-sectional views respectively.

[0426] FIG. 58 shows an isolated view of one of the base end caps, namely, base end cap 592A, which is the same as base end cap 592B, mutatis mutandis. Single-pin contact 582A extends directly through the center of base end cap 592A in the longitudinal direction in alignment with center line 588 of tubular wall 586. Single-pin 582A is also shown in FIG. 50 where single-pin contact 582A is mounted into ballast socket contact 580A. Single-pin contact 582A also includes pin extension 582D that is outwardly positioned from base end cap 592A in the direction towards tubular wall 586. Base end cap 592A is a solid cylinder in configuration as seen in FIGS. 58 and 58A and forms an outer cylindrical wall 660 that is concentric with center line 588 of tubular wall 586 and has opposed flat end walls 662A and 662B that are perpendicular to center line 588. Two cylindrical parallel vent holes 664A and 664B are defined between flat end walls 662A and 662B spaced directly above and below and lateral to single-pin contact 582A. Single-pin contact 582A includes external side pin extension 582C and internal side pin extension 582D that each extend outwardly positioned from opposed flat end walls 662A and 662B, respectively, for electrical connection with ballast socket contact 580A and with integral electronics 602A. Analogous external and internal pin extensions for contact pin 582B likewise exist for electrical connections with ballast socket contact 580B and with integral electronics 602B.

[0427] As also seen in FIG. 58A, base end cap 592A defines an outer circular slot 666 that is concentric with center line 588 of tubular wall 586 and concentric with and aligned proximate to circular wall 660. Circular slot 666 is spaced from cylindrical wall 660 at a convenient distance. Circular slot 666 is of such a width and circular end 590A of tubular wall 586 is of such a thickness that circular end 590A is fitted into circular slot 666 and is thus supported by circular slot 666. Base end cap 592B (not shown in detail) defines another circular slot (not shown) analogous to circular slot 666 that is likewise concentric with center line 588 of tubular wall 586 so that circular end 590B of tubular wall 586 can be fitted into the analogous circular slot of base end cap 592B wherein circular end 590B is also supported. In this manner tubular wall 586 is mounted to base end caps 592A and 592B.

[0428] As also seen in FIG. 58A, base end cap 592A defines inner rectangular slots 668A and 668B that are parallel to each other, but perpendicular with center line 588 of tubular wall 586 and spaced inward from circular slot 666. Rectangular slots 668A and 668B are spaced from circular slot 666 at such a distance that would be occupied by SMD LEDs 606 mounted to LED array circuit boards 594A and 594B within tubular wall 586. Rectangular slots 668A and 668B are of such a width and both circuit board short rectangular edge ends 595A of LED array circuit boards 594A and 594B are of such a thickness that both

circuit board short rectangular edge ends 595A are fitted into rectangular slots 668A and 668B, and are thus supported by rectangular slots 668A and 668B. Base end cap 592B (not shown) defines another two rectangular slots analogous to rectangular slots 668A and 668B that are likewise parallel to each other, and also are perpendicular with center line 588 of tubular wall 586 so that both circuit board short rectangular edge ends 595B of LED array circuit boards 594A and 594B can be fitted into the analogous rectangular slots 668A and 668B of base end cap 592B wherein both circuit board short rectangular edge ends 595B are also supported. In this manner LED array circuit boards 594A and 594B are mounted to base end caps 592A and 592B.

[0429] Circular ends 590A and 590B of tubular wall 586 and also both circuit board short rectangular edge ends 595A and 595B of LED array circuit boards 594A and 594B can be further secured to base end caps 592A and 592B preferably by gluing in a manner known in the art. Other securing methods known in the art of attaching such as cross-pins or snaps can be used. Circular ends 590A and 590B of tubular wall 586 are optionally press fitted to circular slot 666 of base end cap 592A and the analogous circular slot 666 of base end cap 592B.

[0430] FIG. 59 is a sectional view of an alternate LED lamp 670 mounted in tubular wall 676 that is a version of LED lamp 570 as shown in FIG. 52. The sectional view of LED lamp 670 now shows a single SMD LED 606 of LED lamp 670 being positioned at the bottom area 674 of tubular wall 676. LED array circuitry 628 previously described with reference to LED lamp 570 would be the same for LED lamp 670. That is, all thirty SMD LEDs 606 of LED strings 636 of both of the LED arrays 600 of LED lamp 570 would be the same for LED lamp 670, except that now a total of only fifteen SMD LEDs 606 would comprise LED lamp 670 with the fifteen SMD LEDs 606 positioned at the bottom area 674 of tubular wall 676. SMD LEDs 606 are mounted onto the circuit layer 598A, which is separated from metal base layer 598C by dielectric layer 598B of either LED array circuit boards 594A or 594B. Metal base layer 598C is attached to a heat sink 596 separated by thermally conductive grease 597 positioned at the top area 672 of tubular wall 676. Only one of the two LED array circuit boards 594A or 594B is used here to provide illumination on a downward projection only. The reduction to fifteen SMD LEDs 606 of LED lamp 670 from the combined total of thirty SMD LEDs 606 of LED lamp 570 from the two LED array circuit boards 594A and 594B would result in a fifty percent reduction of power demand with an illumination result that would be satisfactory under certain circumstances. Stiffening of LED array circuit boards 594A and 594B for LED lamp 670 is accomplished by single rectangular slots 668A and 668B for both circuit board short edge ends 595A and 595B located in base end caps 592A and 592B, or optionally a vertical stiffening member 678 shown in phantom line that is positioned at the upper area of space 672 between heat sink 596 and the inner side of tubular wall 676 that can extend the length of tubular wall 676 and LED array circuit boards 594A and 594B.

[0431] LED lamp 670 as described above will work for both AC and DC voltage outputs from an existing fluorescent ballast assembly 576. In summary, LED array 600 will ultimately be powered by DC voltage. If existing fluorescent ballast 576 operates with an AC output, bridge rectifier 630 converts the AC voltage to DC voltage. Likewise, if existing

fluorescent ballast 576 operates with a DC voltage, the DC voltage remains a DC voltage even after passing through bridge rectifier 630.

[0432] Another embodiment of a retrofitted LED lamp is shown in FIGS. 60-69. FIG. 60 shows an LED lamp 680 retrofitted to an existing elongated fluorescent fixture 682 mounted to a ceiling 684. A rapid start type ballast assembly 686 including a starter 686A is positioned within the upper portion of fixture 682. Fixture 682 further includes a pair of fixture mounting portions 688A and 688B extending downwardly from the ends of fixture 682 that include ballast electrical contacts shown in FIG. 60A as ballast double contact sockets 690A and 692A and ballast opposed double contact sockets 690B and 692B that are in electrical contact with rapid start ballast assembly 686. Ballast double contact sockets 690A, 692A and 690B, 692B are each double contact sockets in accordance with the electrical operational requirement of a rapid start type ballast. As also seen in FIG. 60A, LED lamp 680 includes bi-pin electrical contacts 694A and 696A that are positioned in ballast double contact sockets 690A and 692A, respectively. LED lamp 680 likewise includes opposed bi-pin electrical contacts 694B and 696B that are positioned in ballast double contact sockets 690B and 692B, respectively. In this manner, LED lamp 680 is in electrical contact with rapid start ballast assembly 686.

[0433] As shown in the disassembled mode of FIG. 61 and also indicated schematically in FIG. 63, LED lamp 680 includes an elongated tubular housing 698 particularly configured as a tubular wall 700 circular in cross-section taken transverse to a center line 702. Tubular wall 700 is made of a translucent material such as plastic or glass and preferably has a diffused coating. Tubular wall 700 has opposed tubular wall circular ends 704A and 704B with cooling vent holes 703A and 703B juxtaposed to tubular wall circular ends 704A and 704B. Optional electric micro fans (not shown) can be used to provide forced air-cooling across the electronic components contained within elongated tubular housing 698. The optional cooling micro fans can be arranged in a push or pull configuration. LED lamp 680 further includes a pair of opposed lamp base end caps 706A and 706B mounted to bi-pin electrical contacts 694A, 696A and 694B, 696B, respectively, for insertion in ballast electrical socket contacts 690A, 692A and 690B, 692B, respectively, in electrical power connection to rapid start ballast assembly 686 so as to provide power to LED lamp 680. Tubular wall 700 is mounted to opposed base end caps 706A and 706B at tubular wall circular ends 704A and 704B, respectively, in the assembled mode as shown in FIG. 60. LED lamp 680 also includes electrical LED array circuit boards 708A and 708B that are rectangular in configuration and each has opposed circuit board short edge ends 710A and 710B, respectively.

[0434] As seen in FIG. 62, circuit boards 708A and 708B are preferably manufactured each from a Metal Core Printed Circuit Boards (MCPCB) consisting of a circuit layer 716A, a dielectric layer 716B, and a metal base layer 716C. Circuit layer 716A is the actual printed circuit foil containing the electrical connections including pads, traces, vias, etc. Electronic integrated circuit components get mounted to circuit layer 716A. Dielectric layer 716B offers electrical isolation with minimum thermal resistance and bonds the circuit metal layer 716A to the metal base layer 716C. Metal base layer 716C is often aluminum, but other metals such as

copper may also be used. The most widely used base material thickness is 0.04" (1.0 mm) in aluminum, although other thicknesses are available. The metal base layer 716C is further attached to heat sink 712 with thermally conductive grease 714 or other material to extract heat away from the LEDs mounted to circuit layer 716A. MCPCBs are designed for attachment to heat sinks using thermal epoxy, Sil-pads, or heat conductive grease 714 between metal base layer 716C and heat sink 712. The metal substrate LED array circuit boards 708A and 708B are each screwed down to heat sink 712 using screws (not shown) or other mounting hardware. The Berquist Company markets their version of a MCPCB called Thermal Clad (T-Clad). Although this embodiment describes a generally rectangular configuration for circuit boards 708A and 708B, it can be appreciated by someone skilled in the art to form circuit boards 708A and 708B into curved shapes or combinations of rectangular and curved portions.

[0435] LED array circuit boards 708A and 708B are positioned within tubular wall 700 and supported by opposed lamp base end caps 706A and 706B. In particular, LED array circuit boards 708A and 708B each have opposed circuit board short edge ends 710A and 710B that are positioned from tubular wall ends 704A and 704B, respectively. As mentioned earlier, LED array circuit boards 708A and 708B each have a circuit layer 716A, a dielectric layer 716B, and a metal base layer 716C respectively with heat sink 712 sandwiched between metal base layers 716C between tubular wall circular ends 704A and 704B, and circuit layers 716A being spaced away from tubular wall 700. LED array circuit boards 708A and 708B are shown in FIG. 61 and indicated schematically in FIG. 64. LED lamp 680 further includes an LED array 718 comprising a total of thirty Lumileds Luxeon SMD LED emitters 724 mounted to both LED array circuit boards 708A and 708B. Integral electronics 602A is positioned on one end of LED array circuit boards 708A and 708B in close proximity to base end cap 706A, and integral electronics 602B is positioned on the opposite end of LED array circuit boards 708A and 708B in close proximity to base end cap 706B. As seen in FIG. 61 and FIG. 64, integral electronics 602A is connected to LED array circuit boards 708A and 708B and also to integral electronics 602B. Integral electronics 602A and 602B are identical in both LED array circuit boards 708A and 708B.

[0436] Integral electronics 720A and 720B can each be located on a separate circuit board (not shown) that is physically detached from the main LED array circuit boards 708A and 708B, but is electrically connected together by means known in the art including headers and connectors, plug and socket receptacles, hard wiring, etc. The fluorescent retrofit LED lamp of the present invention will work with existing and new fluorescent lighting fixtures that contain ballasts that allow for the dimming of conventional fluorescent lamp tubes. For the majority of cases where the ballast cannot dim, special electronics added to integral electronics circuitry 746A and 746B can make existing and new non-dimming fluorescent lighting fixtures now dimmable. Control data can be applied from a remote control center via Radio Frequency (RF) or Infra Red (IR) wireless carrier communications or by Power Line Carrier (PLC) wired communication means. Optional motion control sensors and related control electronic circuitry can also be supplied where now groups of fluorescent lighting fixtures using the fluorescent retrofit LED lamps of the present

invention can be dimmed and/or turned off completely at random or programmed intervals at certain times of the day to conserve electrical energy use.

[0437] The sectional view of FIG. 62 comprises a single SMD LED 724 from each LED array 718 in LED array circuit boards 708A and 708B shown in FIG. 63. SMD LED 724 is representative of one of the fifteen SMD LEDs 724 connected in series in each LED array 718 as shown in FIG. 63. Each SMD LED 724 includes an LED light emitting lens portion 726, an LED body portion 728, and an LED base portion 730. A cylindrical space 732 is defined between circuit layer 716A of each LED array circuit board 708A and 708B and cylindrical tubular wall 700. Each SMD LED 724 is positioned in space 732 as seen in the detailed view of FIG. 62A. LED lens portion 726 is in juxtaposition with the inner surface of tubular wall 700, and LED base portion 730 is mounted to metal base layer 716C of LED array circuit boards 708A and 708B. A detailed view of a single SMD LED 724 shows a rigid LED electrical lead 734 extending from LED base portion 730 to LED array circuit boards 708A and 708B for electrical connection therewith. Lead 734 is secured to LED array circuit boards 708A and 708B by solder 736. An LED center line 738 is aligned transverse to center line 702 of tubular wall 700. As shown in the sectional view of FIG. 62, light is emitted through tubular wall 700 by the two SMD LEDs 724 in substantially equal strength about the entire circumference of tubular wall 700. Projection of this arrangement is such that all fifteen SMD LEDs 724 are likewise arranged to emit light rays in substantially equal strength the entire length of tubular wall 700 in substantially equal strength about the entire 360-degree circumference of tubular wall 700. The distance between LED center line 738 and LED circuit boards 708A and 708B is the shortest that is geometrically possible with heat sink 712 sandwiched between LED array circuit boards 708A and 708B. In FIG. 62A, LED center line 738 is perpendicular to tubular wall center line 702. FIG. 62A indicates a tangential plane 740 relative to the cylindrical inner surface of tubular wall 700 in phantom line at the apex of LED lens portion 726 that is perpendicular to LED center line 738 so that all SMD LEDs 724 emit light through tubular wall 700 in a direction perpendicular to tangential plane 740, so that maximum illumination is obtained from all SMD LEDs 724.

[0438] FIG. 63 shows the total LED electrical circuitry for LED lamp 680. The LED electrical circuitry for both LED array circuit boards 708A and 708B are identically described herein, mutatis mutandis. The total LED circuitry comprises two major circuit assemblies, namely, existing ballast circuitry 742, which includes starter circuit 742A, and LED circuitry 744. LED circuitry 744 includes integral electronics circuitry 746A and 746B, which are associated with integral electronics 720A and 720B. LED circuitry 744 also includes an LED array circuitry 744A and an LED array voltage protection circuit 744B.

[0439] When electrical power, normally 120 volt VAC or 240 VAC at 50 or 60 Hz is applied to rapid start ballast assembly 686, existing ballast circuitry 742 provides an AC or DC voltage with a fixed current limit across ballast socket electrical contacts 692A and 692B, which is conducted through LED circuitry 744 by way of LED circuit bi-pin electrical contacts 696A and 696B, respectively, (or in the event of the contacts being reversed, by way of LED circuit

bi-pin contacts 694A and 694B) to the input of bridge rectifiers 748A and 748B, respectively.

[0440] Rapid start ballast assembly 686 limits the current going into LED lamp 680. Such limitation is ideal for the present embodiment of the inventive LED lamp 680 because LEDs in general are current driven devices and are independent of the driving voltage, that is, the driving voltage does not affect LEDs. The actual number of SMD LEDs 724 will vary in accordance with the actual rapid start ballast assembly 686 used. In the example of the embodiment of LED lamp 680, rapid start ballast assembly 686 provides a maximum current limit of 300 mA, but higher current ratings are also available.

[0441] Voltage surge absorbers 750A, 750B, 750C and 750D are positioned on LED voltage protection circuit 744B for LED array circuitry 744A in electrical association with integral electronics control circuitry 746A and 746B. Bridge rectifiers 748A and 748B are connected to the anode and cathode end buses, respective of LED circuitry 744 and provide a positive voltage V+ and a negative voltage V-, respectively as is also shown in FIGS. 65 and 66. FIGS. 65 and 66 also show schematic details of integral electronics circuitry 746A and 746B. As seen in FIG. 65 an optional resettable fuse 752 is integrated with integral electronics circuitry 746A. Resettable fuse 752 provides current protection for LED array circuitry 744A. Resettable fuse 752 is normally closed and will open and de-energize LED array circuitry 744A in the event the current exceeds the current allowed. The value for resettable fuse 752 is equal to or is lower than the maximum current limit of rapid start ballast assembly 686. Resettable fuse 752 will reset automatically after a cool down period.

[0442] When rapid start ballast assembly 686 is first energized, starter 686A may close creating a low impedance path from bi-pin electrical contact 694A to bi-pin electrical contact 694B, which is normally used to briefly heat the filaments in a fluorescent lamp in order to help the establishment of conductive phosphor gas. Such electrical action is unnecessary for LED lamp 680, and for that reason such electrical connection is disconnected from LED circuitry 744 by way of the biasing of bridge rectifiers 748A and 748B.

[0443] LED array circuitry 744A includes a single LED string 754 with all SMD LEDs 724 within LED string 754 being electrically wired in series. Each SMD LED 724 is preferably positioned and arranged equidistant from one another in LED string 754. Each LED array circuitry 744A includes fifteen SMD LEDs 724 electrically mounted in series within LED string 754 for a total of fifteen SMD LEDs 724 that constitute each LED array 718 in LED array circuit boards 708A and 708B. SMD LEDs 724 are positioned in equidistant relationship with one another and extend substantially the length of tubular wall 700, that is, generally between tubular wall ends 704A and 704B. As shown in FIG. 63, LED string 754 includes a resistor 756 in respective series alignment with LED string 754 at the current anode input. The current limiting resistor 756 is purely optional, because the existing fluorescent ballast used here is already a current limiting device. The resistor 756 then serves as secondary protection devices. A higher number of individual SMD LEDs 724 can be connected in series at each LED string 754. The maximum number of SMD

LEDs 724 being configured around the circumference of the 1.5-inch diameter of tubular wall 700 in the particular example herein of LED lamp 680 is two. Each SMD LED 724 is configured with the anode towards the positive voltage V+ and the cathode towards the negative voltage V-. When rapid start ballast 686 is energized, positive voltage that is applied through resistor 756 to the anode end of LED string 754, and the negative voltage that is applied to the cathode end of LED string 754 will forward bias SMD LEDs 724 connected within LED string 754 and cause SMD LEDs 724 to turn on and emit light.

[0444] Rapid start ballast assembly 686 regulates the electrical current through SMD LEDs 724 to the correct value of 300 mA for each SMD LED 724. Each LED string 754 sees the total current applied to LED array circuitry 744A. Those skilled in the art will appreciate that different ballasts provide different current outputs to drive LEDs that require higher operating currents. To provide additional current to drive the newer high-flux LEDs that require higher currents to operate, the electronic ballast outputs can be tied together in parallel to "overdrive" the LED retrofit lamp of the present invention.

[0445] The total number of LEDs in series within each LED string 754 is arbitrary since each SMD LED 724 in each LED string 754 will see the same current. The maximum number of LEDs is dependent on the maximum power capacity of the ballast. Again in this example, fifteen SMD LEDs 724 are shown connected in each series within each LED string 754. Each of the fifteen SMD LEDs 724 connected in series within each LED string 754 sees this 300 mA. In accordance with the type of ballast assembly 686 used, when rapid start ballast assembly 686 is first energized, a high voltage may be applied momentarily across ballast socket contacts 692A and 692B, which conducts to bi-pin contacts 696A and 696B (or 694A and 694B). This is normally used to help ignite a fluorescent tube and establish conductive phosphor gas, but is unnecessary for this circuit and is absorbed by voltage surge absorbers 750A, 750B, 750C, and 750D to limit the high voltage to an acceptable level for the circuit.

[0446] As can be seen from FIG. 63A, there can be more than fifteen 5 mm LEDs 722 connected in series within each string 754A-754O. There are twenty 5 mm LEDs 722 in this example, but there can be more 5 mm LEDs 722 connected in series within each string 754A-754O. LED array circuitry 744A includes fifteen electrical strings 754 individually designated as strings 754A, 754B, 754C, 754D, 754E, 754F, 754G, 754H, 754I, 754J, 754K, 754L, 754M, 754N and 754O all in parallel relationship with all 5 mm LEDs 722 within each string 754A-754O being electrically wired in series. Parallel strings 754 are so positioned and arranged that each of the fifteen strings 754 is equidistant from one another. LED array circuitry 744A includes twenty 5 mm LEDs 722 electrically mounted in series within each of the fifteen parallel strings of 5 mm LED strings 754A-754O for a total of three-hundred 5 mm LEDs 722 that constitute LED array 718. 5 mm LEDs 722 are positioned in equidistant relationship with one another and extend generally the length of tubular wall 700, that is, generally between tubular wall ends 704A and 704B. As shown in FIG. 63A, each of strings 754A-754O includes an optional resistor 756 designated individually as resistors 756A, 756B, 756C, 756D, 756E, 756F, 756G, 756H, 756I, 756J, 756K, 756L, 756M,

756N, and 756O in respective series alignment with strings 754A-754O at the current input for a total of fifteen resistors 756. Again, a higher number of individual 5 mm LEDs 722 can be connected in series within each LED string 754A-754O. Each 5 mm LED 722 is configured with the anode towards the positive voltage V+ and the cathode towards the negative voltage V-. When LED array circuitry 744A is energized, the positive voltage that is applied through resistors 756A-756O to the anode end of 5 mm LED strings 754A-754O and the negative voltage that is applied to the cathode end of 5 mm LED strings 754A-754O will forward bias 5 mm LEDs 722 connected to LED strings 754A-754O and cause 5 mm LEDs 722 to turn on and emit light.

[0447] Rapid start ballast assembly 686 regulates the electrical current through 5 mm LEDs 722 to the correct value of 20 mA for each 5 mm LED 722. The fifteen 5 mm LED strings 754A-754O equally divide the total current applied to LED array circuitry 744A. Those skilled in the art will appreciate that different ballasts provide different current outputs.

[0448] If the forward drive current for each 5 mm LEDs 722 is known, then the output current of rapid start ballast assembly 686 divided by the forward drive current gives the exact number of parallel strings of 5 mm LEDs 722 in the particular LED array, here LED array 718. The total number of 5 mm LEDs 722 in series within each LED string 754A-754O is arbitrary since each 5 mm LED 722 in each LED string 754A-754O will see the same current. Again in this example, twenty 5 mm LEDs 722 are shown connected in series within each LED string 754. Rapid start ballast assembly 686 provides 300 mA of current, which when divided by the fifteen strings 754 of twenty 5 mm LEDs 722 per LED string 754 gives 20 mA per LED string 754. Each of the twenty 5 mm LEDs 722 connected in series within each LED string 754 sees this 20 mA. In accordance with the type of ballast assembly 686 used, when rapid start ballast assembly 686 is first energized, a high voltage may be applied momentarily across ballast socket contacts 690A, 692A and 690B, 692B, which conduct to pin contacts 694A, 696A and 694B, 696B. Such high voltage is normally used to help ignite a fluorescent tube and establish conductive phosphor gas, but high voltage is unnecessary for LED array circuitry 744A and voltage surge absorbers 750A, 750B, 750C, and 750D suppress the voltage applied by ballast circuitry 742, so that the initial high voltage supplied is limited to an acceptable level for the circuit.

[0449] FIG. 63B shows another alternate arrangement of LED array circuitry 744A. LED array circuitry 744A consists of a single LED string 754 of SMD LEDs 724 including for exposition purposes only, forty SMD LEDs 724 all electrically connected in series. Positive voltage V+ is connected to optional resettable fuse 752, which in turn is connected to one side of current limiting resistor 756. The anode of the first SMD LED in the series string is then connected to the other end of resistor 756. A number other than forty SMD LEDs 724 can be connected within the series LED string 754 to fill up the entire length of the tubular wall of the present invention. The cathode of the first SMD LED 724 in the series LED string 754 is connected to the anode of the second SMD LED 724, the cathode of the second SMD LED 724 in the series LED string 754 is then connected to the anode of the third SMD LED 724, and so forth. The cathode of the last SMD LED 724 in the series

LED string 754 is likewise connected to ground or the negative potential V^- . The individual SMD LEDs 724 in the single series LED string 754 are so positioned and arranged such that each of the forty LEDs is spaced equidistant from one another substantially filling the entire length of the tubular wall 700. SMD LEDs 724 are positioned in equidistant relationship with one another and extend substantially the length of tubular wall 700, that is, generally between tubular wall ends 704A and 704B. As shown in FIG. 63B, the single series LED string 754 includes an optional resistor 756 in respective series alignment with single series LED string 754 at the current input. Each SMD LED 724 is configured with the anode towards the positive voltage V^+ and the cathode towards the negative voltage V^- . When LED array circuitry 744A is energized, the positive voltage that is applied through resistor 756 to the anode end of single series LED string 754 and the negative voltage that is applied to the cathode end of single series LED string 754 will forward bias SMD LEDs 724 connected in series within single series LED string 754, and cause SMD LEDs 724 to turn on and emit light.

[0450] The present invention works ideally with the brighter high flux white LEDs available from Lumileds and Nichia in the SMD packages. Since these new devices require more current to drive them and run on low voltages, the high current available from existing fluorescent ballast outputs with current outputs of 300 mA and higher, along with their characteristically higher voltage outputs provide the perfect match for the present invention. The high-brightness SMD LEDs 724A have to be connected in series, so that each high-brightness SMD LED 724A within the same single LED string 754 will see the same current and therefore output the same brightness. The total voltage required by all the high-brightness SMD LEDs 724A within the same single LED string 754 is equal to the sum of all the individual voltage drops across each high-brightness SMD LED 724A and should be less than the maximum voltage output of rapid start ballast assembly 686.

[0451] FIG. 63C shows a simplified arrangement of the LED array circuitry 744A of SMD LEDs 724 for the overall electrical circuit shown in FIG. 63. AC lead lines 766A, 766B and 768A, 768B and DC positive lead lines 770A, 770B and DC negative lead lines 772A, 772B are connected to integral electronics 720A and 720B. Four parallel LED strings 754 each including a resistor 756 are each connected to DC positive lead lines 770A, 770B on one side, and to LED positive lead line 770 or the anode side of each SMD LED 724 and on the other side. The cathode side of each SMD LED 724 is then connected to LED negative lead line 772 and to DC negative lead lines 772A, 772B directly. AC lead lines 766A, 766B and 768A, 768B simply pass through LED array circuitry 744A.

[0452] FIG. 63D shows a simplified arrangement of the LED array circuitry 744A of 5 mm LEDs 722 for the overall electrical circuit shown in FIG. 63A. AC lead lines 766A, 766B and 768A, 768B and DC positive lead lines 770A, 770B and DC negative lead lines 772A, 772B are connected to integral electronics boards 720A and 720B. Two parallel LED strings 754 each including a single resistor 756 are each connected to DC positive lead lines 770A, 770B on one side, and to LED positive lead line 770 or the anode side of the first 5 mm LED 722 in each LED string 754 on the other side. The cathode side of the first 5 mm LED 722 is

connected to LED negative lead line 772 and to adjacent LED positive lead line 770 or the anode side of the second 5 mm LED 722 in the same LED string 754. The cathode side of the second 5 mm LED 722 is then connected to LED negative lead line 772 and to DC negative lead lines 772A, 772B directly in the same LED string 754. AC lead lines 766A, 766B and 768A, 768B simply pass through LED array circuitry 744A.

[0453] FIG. 63E shows a simplified arrangement of the LED array circuitry 744A of SMD LEDs 724 for the overall LED array electrical circuit shown in FIG. 63B. AC lead lines 766A, 766B and 768A, 768B and DC positive lead lines 770A, 770B and DC negative lead lines 772A, 772B are connected to integral electronics boards 720A and 720B. Single parallel LED string 754 including a single resistor 756 is connected to DC positive lead lines 770A, 770B on one side, and to LED positive lead line 770 on the anode side of the first SMD LED 724 in the LED string 754 on the other side. The cathode side of the first SMD LED 724 is connected to LED negative lead line 772 and to adjacent LED positive lead line 770 or the anode side of the second SMD LED 724. The cathode side of the second SMD LED 724 is connected to LED negative lead line 772 and to adjacent LED positive lead line 770 or the anode side of the third SMD LED 724. The cathode side of the third SMD LED 724 is connected to LED negative lead line 772 and to adjacent LED positive lead line 770 or the anode side of the fourth SMD LED 724. The cathode side of the fourth SMD LED 724 is then connected to LED negative lead line 772 and to DC negative lead lines 772A, 772B directly. AC lead lines 766A, 766B and 768A, 768B simply pass through LED array circuitry 744A.

[0454] The term high-brightness as describing LEDs herein is a relative term. In general, for the purposes of the present application, high-brightness LEDs refer to LEDs that offer the highest luminous flux outputs. Luminous flux is defined as lumens per watt. For example, Lumileds Luxeon high-brightness LEDs produce the highest luminous flux outputs at the present time. Luxeon 5-watt high-brightness LEDs offer extreme luminous density with lumens per package that is four times the output of an earlier Luxeon 1-watt LED and up to 50 times the output of earlier discrete 5 mm LED packages. Luxeon LED emitters are also available in 3-watt packages with Gelcore soon to offer equivalent and competitive products.

[0455] With the new high-brightness SMD LEDs 724A in mind, FIG. 63F shows a single high-brightness SMD LED 724A positioned on an electrical string in what is defined herein as an electrical series arrangement for the overall electrical circuit shown in FIG. 63 and also analogous to FIG. 63B. The single high-brightness SMD LED 724A fulfills a particular lighting requirement formerly fulfilled by a fluorescent lamp.

[0456] Likewise, FIG. 63G shows two high-brightness SMD LEDs 724A in electrical parallel arrangement with one high-brightness SMD LED 724A positioned on each of the two parallel strings for the overall electrical circuit shown in FIG. 63 and also analogous to the electrical circuit shown in FIG. 63A. The two high-brightness SMD LEDs 724A fulfill a particular lighting requirement formerly fulfilled by a fluorescent lamp.

[0457] As shown in the schematic electrical and structural representations of FIG. 64, LED array circuit boards 708A

and 708B for LED array 718, which have mounted thereon LED array circuitry 744A is positioned between integral electronics 720A and 720B that in turn are electrically connected to ballast assembly circuitry 742 by bi-pin electrical contacts 694A, 696A and 694B, 696B, respectively, which are then mounted to base end caps 706A and 706B, respectively. Bi-pin contact 694A includes an external extension 758A that protrudes externally outwardly from base end cap 706A for electrical connection with ballast socket contact 690A and an internal extension 758B that protrudes inwardly from base end cap 706A for electrical connection to integral electronics circuit boards 720A. Bi-pin contact 696A includes an external extension 760A that protrudes externally outwardly from base end cap 706A for electrical connection with ballast socket contact 692A and an internal extension 760B that protrudes inwardly from base end cap 706A for electrical connection to integral electronics circuit boards 720A. Bi-pin contact 694B includes an external extension 762A that protrudes externally outwardly from base end cap 706B for electrical connection with ballast socket contact 690B and an internal extension 762B that protrudes inwardly from base end cap 706B for electrical connection to integral electronics circuit board 720B. Bi-pin contact 696B includes an external extension 764A that protrudes externally outwardly from base end cap 706B for electrical connection with ballast socket contact 692B and an internal extension 764B that protrudes inwardly from base end cap 706B for electrical connection to integral electronics circuit board 720B. Bi-pin contacts 694A, 696A, 694B, and 696B are soldered directly to integral electronics 720A and 720B, respectively mounted onto LED array circuit boards 708A and 708B. In particular, bi-pin contact extensions 758A and 760A are associated with bi-pin contacts 694A and 696A, respectively, and bi-pin contact extensions 762A and 764A are associated with bi-pin contacts 694B and 696B, respectively. Being soldered directly to integral electronics circuit board 720A electrically connects bi-pin contact extensions 758B and 760B. Similarly, being soldered directly to integral electronics circuit board 720B electrically connects bi-pin contact extensions 762B and 764B. It should be noted that someone skilled in the art could use other means of electrically connecting the contact pins 694A, 696A and 694B, 696B to LED array circuit boards 708A and 708B. These techniques include the use of connectors and headers, plugs and connectors, receptacles, etc. among may others.

[0458] FIG. 65 shows a schematic of integral electronics circuit 746A mounted on integral electronics 720A. Integral electronics circuit 746A is also indicated in part in FIG. 63 as connected to LED array circuitry 744A. Integral electronics circuit 746A is in electrical contact with bi-pin contacts 694A, 696A, which are shown as providing either AC or DC voltage. Integral electronics circuit 746A includes bridge rectifier 748A, voltage surge absorbers 750A and 750C, and resettable fuse 752. Integral electronic circuit 746A leads to or from LED array circuitry 744A. It is noted that FIG. 65 indicates the presence of possible AC voltage (rather than possible DC voltage) by an AC wave symbol ~. Each AC voltage could be DC voltage supplied by certain ballast assemblies 686 as mentioned earlier herein. In such a case DC voltage would be supplied to LED array 718 even in the presence of bridge rectifier 748A. It is particularly noted that in such a case, voltage surge absorbers 750A and 750C would remain operative. AC lead lines 766A and 768A

are in a power connection with ballast assembly 686. DC lead lines 770A and 772A are in positive and negative direct current relationship with LED array circuitry 744A. Bridge rectifier 748A is in electrical connection with four lead lines 766A, 768A, 770A and 772A. A voltage surge absorber 750A is in electrical contact with lead lines 766A and 768A and voltage surge absorber 750C is positioned on lead line 766A. Lead lines 770A and 772A are in electrical contact with bridge rectifier 748A and in power connection with LED array circuitry 744A. Fuse 752 is positioned on lead line 770A between bridge rectifier 748A and LED array circuitry 744A.

[0459] FIG. 66 shows a schematic of integral electronics circuit 746B mounted on integral electronics 720B. Integral electronics circuit 746B is also indicated in part in FIG. 63 as connected to LED array circuitry 744A. Integral electronics circuit 746B is a close mirror image or electronics circuit 746A mutatis mutandis. Integral electronics circuit 746B is in electrical contact with bi-pin contacts 694B, 696B, which are shown as providing either AC or DC voltage. Integral electronics circuit 746B includes bridge rectifier 748B, voltage surge absorbers 750B and 750D. Integral electronic circuit 746B leads to or from LED array circuitry 744A. It is noted that FIG. 66 indicates the presence of possible AC voltage (rather than possible DC voltage) by an AC wave symbol ~. Each AC voltage could be DC voltage supplied by certain ballast assemblies 686 as mentioned earlier herein. In such a case DC voltage would be supplied to LED array 718 even in the presence of bridge rectifier 748B. It is particularly noted that in such a case, voltage surge absorbers 750B and 750D would remain operative. AC lead lines 766B and 768B are in a power connection with ballast assembly 686. DC lead lines 770B and 772B are in positive and negative direct current relationship with LED array circuitry 744A. Bridge rectifier 748B is in electrical connection with four lead lines 766B, 768B, 770B and 772B. A voltage surge absorber 750B is in electrical contact with lead lines 766B and 768B and voltage surge absorber 750D is positioned on lead line 768B. Lead lines 770B and 772B are in electrical contact with bridge rectifier 748B and in power connection with LED array circuitry 744A.

[0460] FIGS. 65 and 66 show the lead lines going into and out of LED circuitry 744 respectively. The lead lines include AC lead lines 766B and 768B, positive DC voltage 770B, and DC negative voltage 772B. The AC lead lines 766B and 768B are basically feeding through LED circuitry 744, while the positive DC voltage lead line 770B and negative DC voltage lead line 772B are used primarily to power the LED array 718. DC positive lead lines 770A and 770B are the same as LED positive lead line 770 and DC negative lead lines 772A and 772B are the same as LED negative lead line 772. LED array circuitry 744A therefore consists of all electrical components and internal wiring and connections required to provide proper operating voltages and currents to 5 mm LEDs 722 or to SMD LEDs 724 connected in parallel, series, or any combinations of the two.

[0461] FIGS. 67 and 67A show a close-up of elongated tubular housing 698 with details of cooling vent holes 703A and 703A located on opposite ends of elongated tubular housing 698 in both side and cross-sectional views respectively.

[0462] FIG. 68 shows an isolated view of one of the base end caps, namely, base end cap 706A, which is analogous to base end cap 706B, *mutatis mutandis*. Bi-pin electrical contacts 694A, 696A extend directly through base end cap 706A in the longitudinal direction in alignment with center line 702 of tubular wall 700 with bi-pin external extensions 758A, 760A and internal extensions 758B, 760B shown. Base end cap 706A is a solid cylinder in configuration as seen in FIGS. 68 and 68A and forms an outer cylindrical wall 774 that is concentric with center line 702 of tubular wall 700 and has opposed flat end walls 776A and 776B that are perpendicular to center line 702. Two cylindrical parallel vent holes 778A and 778B are defined between end walls 776A and 776B in vertical alignment with center line 702.

[0463] As also seen in FIG. 68A, base end cap 706A defines an outer circular slot 780 that is concentric with center line 702 of tubular wall 700 and concentric with and aligned proximate to circular wall 774. Outer circular slot 780 is of such a width and circular end 704A of tubular wall 700 is of such a thickness and diameter that outer circular slot 780 accepts circular end 704A into a fitting relationship and circular end 704A is thus supported by circular slot 780. Base end cap 706B defines another outer circular slot (not shown) analogous to outer circular slot 780 that is likewise concentric with center line 702 of tubular wall 700 so that circular end 704B of tubular wall 700 can be fitted into the analogous circular slot of base end cap 706B wherein circular end 704B of tubular wall 700 is also supported. In this manner tubular wall 700 is mounted to end caps 706A and 706B.

[0464] As also seen in FIG. 68A, base end cap 706A defines inner rectangular slots 782A and 782B that are parallel to each other, but perpendicular with center line 702 of tubular wall 700 and spaced inward from outer circular slot 780. Rectangular slots 782A and 782B are spaced from outer circular slot 780 at such a distance that would be occupied by SMD LEDs 724 mounted to LED array circuit boards 708A and 708B within tubular wall 700. Rectangular slots 782A and 782B are of such a width and circuit board short rectangular edge ends 710A of LED array circuit boards 708A and 708B is of such a thickness that circuit board short rectangular edge ends 710A are fitted into rectangular slots 782A and 782B, and are thus supported by rectangular slots 782A and 782B. Base end cap 706B (not shown) defines another two rectangular slots analogous to rectangular slots 782A and 782B that are likewise parallel to each other, but perpendicular with center line 702 of tubular wall 700 so that circuit board short rectangular edge ends 710B of LED array circuit boards 708A and 708B can be fitted into the analogous rectangular slots 782A and 782B of base end cap 706B wherein circuit board short rectangular edge ends 710B are also supported. In this manner LED array circuit boards 708A and 708B are mounted to end caps 706A and 706B.

[0465] Circular ends 704A and 704B of tubular wall 700 and also circuit board short rectangular edge ends 710A and 710B of LED array circuit boards 708A and 708B are secured to base end caps 706A and 706B preferably by gluing in a manner known in the art. Other securing methods known in the art of attaching such as cross-pins or snaps can be used. Circular ends 704A and 704B of tubular wall 700

are optionally press fitted to circular slot 780 of base end cap 706A and the analogous circular slot 780 of base end cap 706B.

[0466] FIG. 69 is a sectional view of an alternate LED lamp 784 mounted in tubular wall 790 that is a version of LED lamp 680 as shown in FIG. 62. The sectional view of LED lamp 784 now shows a single SMD LED 724 of LED lamp 784 being positioned at the bottom area 788 of tubular wall 790. LED array circuitry 744 previously described with reference to LED lamp 680 would be the same for LED lamp 784. That is, all thirty SMD LEDs 724 of LED strings 754 of both of the LED arrays 718 of LED lamp 680 would be the same for LED lamp 784, except that now a total of only fifteen SMD LEDs 724 would comprise LED lamp 784 with the fifteen SMD LEDs 724 positioned at the bottom area 788 of tubular wall 790. SMD LEDs 724 are mounted onto the circuit layer 716A, which is separated from metal base layer 716C by dielectric layer 716B of either LED array circuit boards 708A or 708B. Metal base layer 716C is attached to a heat sink 712 separated by thermally conductive grease 714 positioned at the top area 786 of tubular wall 790. Only one of the two LED array circuit boards 708A or 708B is used here to provide illumination on a downward projection only. The reduction to fifteen SMD LEDs 724 of LED lamp 784 from the combined total of thirty SMD LEDs 724 of LED lamp 680 from the two LED array circuit boards 708A and 708B would result in a fifty percent reduction of power demand with an illumination result that would be satisfactory under certain circumstances. Stiffening of LED array circuit boards 708A and 708B for LED lamp 784 is accomplished by single rectangular slots 782A and 782B for circuit board short edge ends 710A and 710B located in base end caps 706A and 706B, or optionally a vertical stiffening member 792 shown in phantom line that is positioned at the upper area of space 786 between heat sink 712 and the inner side of tubular wall 790 that can extend the length of tubular wall 790 and LED array circuit boards 708A and 708B.

[0467] LED lamp 784 as described above will work for both AC and DC voltage outputs from an existing fluorescent rapid start ballast assembly 686. In summary, LED array 718 will ultimately be powered by DC voltage. If existing fluorescent rapid start ballast assembly 686 operates with an AC output, bridge rectifiers 748A and 748B convert the AC voltage to DC voltage. Likewise, if existing fluorescent rapid start ballast 686 operates with a DC voltage, the DC voltage remains a DC voltage even after passing through bridge rectifiers 748A and 748B.

[0468] Another embodiment of a retrofitted LED lamp is shown in FIGS. 70 and 71 that show an LED lamp 794 retrofitted to an existing elongated fluorescent fixture 796 mounted to a wall 798. A rapid start type ballast assembly 800 is positioned within fixture 796. Fluorescent fixture 796 further includes a pair of ballast double electrical socket contacts 802A and 802B that are in electrical contact with bi-pin electrical contacts 804A and 804B of LED 794. In a manner analogous to the structure of LED lamp 680 relative to rapid start ballast assembly 686 described earlier, LED lamp 794 is in electrical contact with rapid start ballast assembly 800.

[0469] LED lamp 794 includes an elongated tubular housing 806 particularly configured as a tubular wall 808 circular in cross-section. Tubular wall 808 includes an apex portion

812 and a pair of pier portions **814A** and **814B**. Tubular wall **808** is made of a translucent material such as plastic or glass and preferably has a diffused coating. Tubular wall **808** has opposed tubular wall circular ends **816A** and **816B**. LED lamp **794** also includes electrical LED array upper and lower circuit boards **818** and **820**, respectively, that are positioned within tubular housing **806**, and that are configured to conform with apex portion **812** and pier portions **814A** and **814B**. The electric circuitry for LED lamp **794** is analogous to the electric circuitry as described relative to LED lamp **680**. Circuit boards **818** and **820** are preferably manufactured each from a Metal Core Printed Circuit Boards (MCPCB) and comprise circuit layers **818A** and **820A**, respectively, dielectric layers **818B** and **820B**, respectively, and metal base layers **818C** and **820C**, respectively. A heat sink **822** is mounted to metal base layers **818C** and **820C**. A plurality of upper LEDs **826** and a plurality of lower LEDs **828** are mounted to and electrically connected to circuit boards **818** and **820**, respectively, and in particular to circuit layers **818A** and **820A**, respectively. LEDs **826** and **828** can selectively be typical 5 mm LEDs, 1 mm LEDs, SMD LEDs, and optionally can be high-brightness LEDs.

[0470] FIG. 72 is a section view of an LED lamp **828A** that is for mounting to an instant start ballast assembly (not shown) with opposed single pin contacts generally analogous to LED lamp **570** discussed previously. FIG. 72 also represents a section view of an LED lamp **828B** with opposed bi-pin contacts generally analogous to LED lamp **680** discussed previously. FIG. 72A is an interior view of one circular single pin base end cap **830A** taken in isolation representing both opposed base end caps of LED lamp **828A**. FIG. 72B is an interior view of one circular bi-pin base end cap **830B** taken in isolation representing both opposed base end caps of LED lamp **828B**.

[0471] LED lamp **828A** and LED lamp **828B** both include a lamp tubular housing **832** having a tubular wall **834** circular in configuration. Three elongated rectangular metal substrate circuit boards **836**, **838**, and **840** mounted in lamp housing **832** spaced from tubular wall **834** are connected at their long edges so as to form a triangle in cross-section. Other configurations including squares, hexagons, etc. can be used. Circuit boards **836**, **838**, and **840** include circuit layers **836A**, **838A**, and **840A** respectively; dielectric layers **836B**, **838B**, and **840B** respectively, and metal base layers **836C**, **838C**, and **840C** respectively. Specially extruded heat sink **842** is mounted to metal base layers **836C**, **838C**, and **840C** respectively. Metal base layers **836C**, **838C**, and **840C** are connected at their rectangular edges to the single pin base end caps such as single pin base end cap **830A** to secure circuit boards **836**, **838**, and **840** in the triangular cross-sectional shape. Heat sink **842** is mounted to the inner surfaces of metal base layers **836C**, **838C**, and **840C**. LEDs **844A**, **844B**, and **844C** each represent a plurality of LEDs mounted in linear alignment on each metal substrate boards **836**, **838**, and **840** respectively, in particular to circuit layers **836A**, **838A**, and **840A** respectively. The electrical connections are analogous to those described in relation to LED lamp **570** previously described herein. Metal substrate circuit boards **836**, **838**, and **840** as are LEDs **844A**, **844B**, and **844C** are spaced from tubular wall **834**.

[0472] Circular single pin base end cap **830A** shown in FIG. 72A is one of the two base end caps for triangular LED lamp **828A**, and is analogous to base end caps **592A** and

592B of LED lamp **570** shown in FIGS. 50 and 51. Triangularly arranged rectangular mounting slots **846A**, **846B**, and **846C** formed in base end cap **830A** are aligned to receive the tenon ends of metal substrate circuit boards **836**, **838**, and **840**, which are rectangular in shape and are analogous to circuit board short end edges **595A** and **595B** of LED array circuit boards **594A** and **594B** shown in FIG. 51. An outer circular mounting slot **848** formed in base end cap **830A** is aligned to receive the circular end of tubular wall **834**, and the opposed base end cap likewise forms a circular end slot that receives the opposed end of tubular wall **834**, so that both slots mount both ends of tubular wall **834** of triangular LED lamp **828A**. A single pin contact **850** is located at the center of circular single pin base end cap **830A**. Single pin base end cap **830A** also defines three base end cap venting holes **852A**, **852B**, and **852C** located between circular slot **848** and each rectangular slot **846A**, **846B**, and **846C**. Locations for venting holes **852A**, **852B**, and **852C** can be positioned anywhere within base end cap **830A**.

[0473] Circular bi-pin base end cap **830B** shown in FIG. 72B is one of the two base end caps for triangular LED lamp **828B** and is analogous to base end caps **706A** and **706B** of LED lamp **680** shown in FIGS. 60 and 61. Triangular arranged rectangular mounting slots **852A**, **852B**, and **852C** formed in bi-pin base end cap **830B** are aligned to receive the tenon ends of metal substrate circuit boards **836**, **838** and **840**, which are rectangular in shape and are analogous to circuit board short end edges **710A** and **710B** of LED array circuit boards **708A** and **708B** shown in FIG. 61. An outer circular mounting slot **854** formed in base end cap **830B** is aligned to receive the circular end of tubular wall **834**, and the opposed base end cap likewise forms a circular end slot that receives the other end of tubular wall **834**, so that both slots mount both ends of tubular wall **834** of triangular LED lamp **828B**. Bi-pin contacts **856A** and **856B** are located at the center area of circular bi-pin base end cap **830B**. Bi-pin base end cap **830B** also defines three base end cap venting holes **858A**, **858B**, and **858C** located between circular slot **854** and each rectangular slot **852A**, **852B**, and **852C**. Locations for venting holes **858A**, **858B**, and **858C** can be positioned anywhere within base end cap **830B**.

[0474] Although the invention thus far set forth has been described in some detail by way of illustration and example for purposes of clarity and understanding, it will of course, be understood that various changes and modifications may be made in the form, details, and arrangements of the parts without departing from the scope of the invention. For example, more than three metal substrate circuit boards can be mounted in any of LED lamps **570**, **670**, **680**, **784**, **794**, and **828**.

[0475] FIGS. 73, 73A, 74, 74A, 74B, 75, 75A, 75B, 75C, 76, 76A, 77, 78, 78A, 79A, and 79B show various embodiments and details of the present invention that is directed to the control of the delivery of electrical power from a ballast assembly to an LED array positioned in a tube as described herein.

[0476] In certain conditions and locations, direct hard-wire connections and wireless transmissions may not be possible, or may not offer the best performance. The use of existing power lines as a data information carrier serves as an alternate method of getting data input control to the

on-board computer. X10 protocol and other PLC methods can be used. Thus, the data control signal can also be a direct hard-wire connection including DMX512, RS232, Ethernet, DALI, Lonworks, RDM, CEBus Standard EIA-600, X10, and other Power Line Carrier Communication (PLC) protocols.

[0477] FIG. 73 shows an embodiment of the present invention, in particular shown as a schematic block diagram of an LED lamp 860 that includes an LED array 862 comprising a plurality of LEDs positioned in an elongated translucent tube 864. LED array 862 is connected to a power supply comprising a source of VAC power 866 electrically connected to a ballast 868, which is external to tube 864. An electrical connection 870A positioned in tube 864 is powered from ballast 868 and transmits AC power to AC-DC power converter 869, which in turn transmits DC power to an on-off switch 872 also positioned in tube 864 by way of electrical connection 870B. Power from ballast 868 can be either AC or DC voltage. In the case of DC power going into AC-DC power converter 869, DC power will continue to be sent to on-off switch 872. Switch 872 is electrically connected to LED array 862 by electrical connection 874. LED array 862 contains the necessary electrical components to further reduce the power transmitted by switch 972 by way of electrical connection 874 to properly drive the plurality of LEDs in LED array 862.

[0478] A manual control unit 876 positioned external to LED lamp 860 is operationally connected to on-off switch 872 by any of three optional signal paths 878A, 878B, or 878C. Signal path 878A is an electrical signal line wire extending directly from manual control unit 876 to switch 872. Signal path 878B is a wireless signal line shown in dash line extending directly to switch 872. Signal path 878C is a signal line wire that is connected to a PLC line 880 that extends from VAC 866 through tube 860 to switch 872. Switch 872 also contains the necessary electronics to decode the data information imposed on PLC line 880 via signal path 878C. Manual control unit 876 may be powered from an external VAC power source 866 or directly from switch 872.

[0479] In operation, manual activation of manual control unit 876 sends a signal by whichever signal line is being used of signal lines 878A, 878B, or 878C with the result that switch 872 is operated to turn either on or off, depending on the prior setting. If, for example, LED array is in an illumination mode with power coming from ballast 868 through switch 872, operation of switch 872 from the on mode to the off mode will cause termination of electrical power from ballast 868 to LED array 862, so that LED array will cease to illuminate. If, on the other hand, LED array 862 is in a non-illumination mode, with no power passing from ballast 868 through switch 872, operation of switch 872 from the off mode to the on mode will cause passage of electrical power from ballast 868 to LED array 862, so that LED array 862 will be in an illumination mode.

[0480] FIG. 73A shows another embodiment of the present invention, in particular shown as a schematic block diagram of an LED lamp 882 that includes an LED array 884 comprising a plurality of LEDs positioned in a translucent tube 886. LED array 884 is connected to a power supply comprising a source of VAC power 888 electrically connected to a ballast 890, which is external to tube 886. An

electrical connection 892A positioned in tube 886 is powered from ballast 890 and transmits AC power to AC-DC power converter 891, which in turn transmits DC power to a computer 894 by way of electrical connection 892B and to dimmer 898 by way of a similar electrical connection (not shown). Both computer 894 and dimmer 898 are also positioned in tube 886. Power from ballast 890 can be either AC or DC voltage. In the case of DC power going into AC-DC power converter 891, DC power will continue to be sent to computer 894 and dimmer 898. Computer 894 is electrically and operatively connected by an electrical control connection 896 to dimmer 898. An electrical connection 900 connects dimmer 898 to LED array 884. Dimmer 898 will contain the necessary electronics needed to decode the data control signals sent by computer 894, and will provide the proper current drive power required to operate LED array 884. Single LED array 884 controlled by dimmer 898 can represent multiple LED arrays 884 each correspondingly controlled by one of a plurality of dimmers 898 (not shown), wherein the plurality of dimmers 898 are each independently controlled by computer 894. Computer 894 includes a microprocessor, a program installed therein, memory, input/output means, and addressing means.

[0481] A manual control unit 902 positioned external to LED lamp 882 is operationally connected to computer 894 by any of three optional alternative signal paths 904A, 904B, or 904C connected to a PLC line 906 extending from VAC 888 through tube 886 to computer 894. Signal path 904A is an electrical signal line wire extending directly from manual control unit 902 to computer 894. Signal path 904B is a wireless signal path shown in dash line extending directly to computer 894. Signal path 904C is a signal line wire that is connected to a PLC line 906 that extends from VAC 888 through tube 886 to computer 894. Computer 894 also contains the necessary electronics to decode the data information imposed on PLC line 906 via signal path 904C. Manual control unit 902 may be powered from an external VAC power source 888 or directly from computer 894.

[0482] Activation of manual control unit 902 activates computer 894 to signal dimmer 898 to increase or decrease delivery of electrical power to LED array 884 by a power factor that is preset in computer 894. The delivery power factor can be preset to range anywhere from a theoretical reduced power deliver of zero percent from dimmer 898 to LED array 884 to any reduction of power of 100 percent delivery of power, but as a practical matter the actual setting would be in a middle range of power delivery to LED array 884 depending on circumstances. Computer 894 includes a computer signal input port and a computer signal output port. Manual control unit 902 is manually operable between an first activation mode wherein a control signal is sent to the computer signal input port by way of signal paths 904A, 904B, or 904C to activate computer 894 to send from the computer signal output port, a computer output signal to dimmer 898 to operate at the preset power less than full power, and a second activation mode wherein a control signal is sent to the computer input signal port by way of signal paths 904A, 904B, or 904C to activate computer 894 to send from the computer signal output port, a computer output signal to dimmer 898 to operate LED array 884 at full power.

[0483] FIG. 74 shows another embodiment of the present invention, in particular shown as a schematic block diagram

of an LED lamp 908 that includes an LED array 910 comprising a plurality of LEDs positioned in a translucent tube 912. LED array 910 is connected to a power supply comprising a source of VAC power 914 electrically connected to a ballast 916, which is external to tube 912. An electrical connection 918A positioned in tube 912 is powered from ballast 916 and transmits AC power to AC-DC power converter 917, which in turn transmits DC power to a timer 920 by way of electrical connection 918B and to an on-off switch 924 by way of a similar electrical connection (not shown). Both timer 920 and switch 924 are also positioned in tube 912. Power from ballast 916 can be either AC or DC voltage. In the case of DC power going into AC-DC power converter 917, DC power will continue to be sent to timer 920 and switch 924. Timer 920 is electrically and operatively connected by an electrical control connection 922 to switch 924. An electrical connection 926 connects switch 924 to LED array 910. LED array 910 contains the necessary electrical components to further reduce the power transmitted by switch 924 by way of electrical connection 926 to properly drive the plurality of LEDs in LED array 910.

[0484] A manual timer control unit 928 positioned external to LED lamp 908 is operationally connected to timer 920 by any of three optional alternative signal paths 930A, 930B, or 930C. Signal path 930A is an electrical signal line wire extending directly from manual control unit 928 to timer 920. Signal path 930B is a wireless signal path shown in dash line extending directly to timer 920. Signal path 930C is a signal line wire that is connected to a PLC line 932 that extends from VAC 914 through tube 912 to timer 920. Timer 920 also contains the necessary electronics to decode the data information imposed on PLC line 932 via signal path 930C. Manual control unit 928 may be powered from an external VAC power source 914 or directly from timer 920.

[0485] In operation, manual timer control unit 928 is manually set to activate timer 920 at a particular on mode time to close switch 924, and in addition at a particular off mode time to open switch 924. In the on mode, power is passed from ballast 916, to power converter 917, to switch 924, and then to LED array 910. In the off mode, switch 924 terminates the transmission of power from ballast 916, to power converter 917, to switch 924, and then to LED array 910.

[0486] Referring now to FIGS. 73A and 74, computer 894 can be replaced with timer 920 in operational control of dimmer 898 in FIG. 73A, and timer 20 can be replaced with computer 894 in operational control of switch 924 in FIG. 74 to achieve the similar functionality and illumination results.

[0487] FIG. 74A shows another embodiment of the present invention, in particular shown is a schematic block diagram of an LED lamp 938 that includes an LED array 940 comprising a plurality of LEDs positioned in a translucent tube 942. LED array 940 is connected to a power supply comprising a source of VAC power 944 electrically connected to a ballast 946, which is external to tube 942. An electrical connection 948A positioned in tube 942 is powered from ballast 946 and transmits AC power to AC-DC power converter 947, which in turn transmits DC power to a computer 950 by way of electrical connection 948B and to dimmer 954 by way of a similar electrical connection (not

shown). Both computer 950 and dimmer 954 are also positioned in tube 942. Power from ballast 946 can be either AC or DC voltage. In the case of DC power going into AC-DC power converter 947, DC power will continue to be sent to computer 950 and dimmer 954. Computer 950 is electrically and operatively connected by an electrical control connection 952 to dimmer 954. An electrical connection 956 connects dimmer 954 to LED array 940. Dimmer 954 will contain the necessary electronics needed to decode the data control signals sent by computer 950, and will provide the proper current drive power required to operate LED array 940. Single LED array 940 controlled by dimmer 954 can represent multiple LED arrays 940 each correspondingly controlled by one of a plurality of dimmers 954 (not shown), wherein the plurality of dimmers 954 are each independently controlled by computer 950. Computer 950 includes a microprocessor, a program installed therein, memory, input/output means, and addressing means.

[0488] An on-off switch 958 external to tube 942 is operationally connected to computer 950. A timer 960 also external to tube 942 is positioned adjacent to or integral with switch 958, is operationally connected to switch 958 by an electrical connection 962. Timer 960 can be manually set to automatically activate switch 958 to an on mode or an off mode at preset times wherein computer 950 is activated by switch 958 to signal dimmer 954 to increase or decrease delivery of electrical power to LED array 940 by a power factor that is preset in either dimmer 954 or in computer 950. The reduced delivery power factor can be preset to range anywhere from a theoretical zero percent delivery of power from dimmer 954 to LED array 940 to approaching a theoretical 100 percent delivery of power, but as a practical matter the actual reduced power setting would be in a middle range of power delivery to LED array 940 depending on the circumstances.

[0489] Switch 958 is operationally connected to computer 950 by any of three optional alternative signal paths 964A, 964B, or 964C. Signal path 964A is an electrical signal line wire extending directly from switch 958 to computer 950. Signal path 964B is a wireless signal path shown in dash line extending directly to computer 950. Signal path 964C is a signal line wire that is connected to a PLC line 966 that extends from VAC 944 through tube 942 to computer 950. Computer 950 also contains the necessary electronics to decode the data information imposed on PLC line 966 via signal path 964C. Timer 960 and switch 958 may be individually or mutually powered from an external VAC power source 944 or directly from computer 950.

[0490] Computer 950 includes a computer signal input port and a computer signal output port. Switch 958 is operable between an first activation mode wherein a control signal is sent by switch 958 to the computer signal input port by way of signal paths 964A, 964B, or 964C to activate computer 950 to send from the computer signal output port, a computer output signal to dimmer 954 to operate at the preset power less than full power, and a second activation mode wherein a control signal is sent by switch 958 to the computer input signal port by way of signal paths 964A, 964B, or 964C to activate computer 950 to send from the computer signal output port, a computer output signal to dimmer 954 to operate LED array 940 at full power.

[0491] FIG. 74B shows another embodiment of the present invention. It is similar to FIG. 74A with the timer

and switch now inside the LED lamp. In particular is shown a schematic block diagram of an LED lamp **968** that includes an LED array **970** comprising a plurality of LEDs positioned in a translucent tube **972**. LED array **970** is connected to a power supply comprising a source of VAC power **974** electrically connected to a ballast **976**, which is external to tube **972**. An electrical connection **978A** positioned in tube **972** is powered from ballast **976** and transmits AC power to AC-DC power converter **977**, which in turn transmits DC power to a timer **980** by way of electrical connection **978B**, to on-off switch **984**, to computer **986**, and to dimmer **990** by way of similar electrical power connections (not shown). Timer **980**, switch **984**, computer **986**, and dimmer **990** are all positioned in tube **972**. Power from ballast **976** can be either AC or DC voltage. In the case of DC power going into AC-DC power converter **977**, DC power will continue to be sent to timer **980**, switch **984**, computer **986**, and dimmer **990**. Computer **986** is electrically and operatively connected by an electrical control connection **988** to dimmer **990**. An electrical connection **992** connects dimmer **990** to LED array **970**. Dimmer **990** will contain the necessary electronics needed to decode the data control signals sent by computer **986**, and will provide the proper current drive power required to operate LED array **970**. Single LED array **970** controlled by dimmer **990** can represent multiple LED arrays **970** each correspondingly controlled by one of a plurality of dimmers **990** (not shown), wherein the plurality of dimmers **990** are each independently controlled by computer **986**. Computer **986** includes a microprocessor, a program installed therein, memory, input/output means, and addressing means.

[0492] Timer **980** is activated at preset times that in turn activate or deactivate switch **984** by electrical connection **982**. Such time presetting can be done, for example, at the assembly site or programmable by the customer. The activation of switch **984** by timer **980** signals the activation of computer **986** to emit a signal from the computer output signal port relating to dimmer **990** to control the power input to LED array **970** in accordance with the computer command. Thus, the degree of illumination emitted by LED array **970** can be increased or decreased at set times.

[0493] FIG. 75 shows another embodiment of the present invention. In particular shown is a schematic block diagram of an LED lamp **994** that includes an LED array **996** comprising a plurality of LEDs positioned in a translucent tube **998**. LED array **996** is connected to a power supply comprising a source of VAC power **1000** electrically connected to a ballast **1002**, which is external to tube **998**. An electrical connection **1004A** positioned in tube **998** is powered from ballast **1002** and transmits AC power to AC-DC power converter **1003**, which in turn transmits DC power to an on-off switch **1006** also positioned in tube **998** by way of electrical connection **1004B**. An occupancy motion sensor **1010** also positioned in tube **998** transmits control signals to switch **1006** by way of signal line **1012**. Electrical power is transmitted to sensor **1010** also by electrical connection **1004B** connected to power converter **1003**. Sensor **1010** may be powered by AC or DC voltage depending on the model and type of design. Occupancy motion sensor control in response to the movement or presence of a person in the illumination area of LED array **996** are set at the place of manufacture or assembly in accordance with methods known in the art. Power from ballast **1002** can be either AC or DC voltage. In the case of DC power going into AC-DC

power converter **1003**, DC power will continue to be sent to on-off switch **1006** and occupancy motion sensor **1010**. Switch **1006** is electrically connected to LED array **996** by electrical connection **1008**. LED array **996** contains the necessary electrical components to further reduce the power transmitted by switch **1006** by way of electrical connection **1008** to properly drive the plurality of LEDs in LED array **996**.

[0494] When sensor **1010** detects movement or the presence of a person in the illumination area of LED array **996**, an instant on-mode output signal is transmitted from sensor **1010** to switch **1006** wherein power is transmitted through switch **1006** to LED array **996**. When sensor **1010** ceases to detect movement or the presence of a person in the illumination area of LED array **996**, a delayed off-mode signal is transmitted from sensor **1010** to switch **1006** wherein switch **1006** is turned to the off-mode and power from ballast **1002** to power converter **1003** through switch **1006** and to LED array **996** is terminated. At such time sensor **1010** again senses motion or the presence of a person in the illumination area of LED array **996**, an instant on-mode signal is again transmitted from sensor **1010** to switch **1006** wherein switch **1006** is turned to the on-mode and power from ballast **1002** to power converter **1003** through switch **1006** and to LED array **996** is activated, so that LED array **996** illuminates the area. The time delay designed into the off mode prevents intermittent illumination cycling in the area around LED array **996** and can be preset at the factory or can be set in the field.

[0495] FIG. 75A shows another embodiment of the present invention. In particular shown is a schematic block diagram of an LED lamp **1014** that includes an LED array **1016** comprising a plurality of LEDs positioned in a translucent tube **1018**. LED array **1016** is connected to a power supply comprising a source of VAC power **1020** electrically connected to a ballast **1022**, which is external to tube **1018**. An electrical connection **1024A** positioned in tube **1018** is powered from ballast **1022** and transmits AC power to AC-DC power converter **1023**, which in turn transmits DC power to a computer **1026** by way of electrical connection **1024B** and to dimmer **1030** by way of a similar electrical connection (not shown). Both computer **1026** and dimmer **1030** are also positioned in tube **1018**. Computer **1026** has a computer input signal port and a computer output signal port. An occupancy motion sensor **1034** also positioned in tube **1018** transmits control signals to computer **1026** by way of input control signal line **1036** to the computer input signal port of computer **1026**. Electrical power is transmitted to sensor **1034** also by electrical connection **1024B** connected to power converter **1023**. Sensor **1034** may be powered by AC or DC voltage depending on the model and type of design. Occupancy motion sensor control in response to the movement or presence of a person in the illumination area of LED array **1016** are set at the place of manufacture or assembly in accordance with methods known in the art. Power from ballast **1022** can be either AC or DC voltage. In the case of DC power going into AC-DC power converter **1023**, DC power will continue to be sent to computer **1026**, occupancy motion sensor **1034**, and dimmer **1030**. Computer **1026** is electrically and operatively connected by an electrical control connection **1028** to dimmer **1030**. An electrical connection **1032** connects dimmer **1030** to LED array **1016**. Dimmer **1030** will contain the necessary electronics needed to decode the data control signals sent by

the computer output signal port of computer **1026**, and will provide the proper current drive power required to operate LED array **1016**. Single LED array **1016** controlled by dimmer **1030** can represent multiple LED arrays **1016** each correspondingly controlled by one of a plurality of dimmers **1030** (not shown), wherein the plurality of dimmers **1030** are each independently controlled by computer **1026**. Computer **1026** includes a microprocessor, a program installed therein, memory, input/output means, and addressing means.

[0496] When sensor **1034** detects motion or the presence of a person in the illumination area of LED array **1016**, sensor **1034** sends a signal to the computer signal input port of computer **1026** by way of signal line **1036** wherein computer **1026** then sends a signal from the computer signal output port to dimmer **1030** to provide full power to LED array **1016** for full illumination. When sensor **1034** ceases to detect motion or the presence of a person in the illumination area of LED array **1016** after a set time period, a sensor signal to computer **1026** by way of signal line **1036** causes computer **1026** to send a computer output signal to dimmer **1024** to decrease the power to LED array **1016** by a preset amount, so that LED array **1016** reduces full illumination of the area, that is, illumination is continued, but reduced to a preset illumination output.

[0497] Sensor **1034**, computer **1026**, and dimmer **1030** can be optionally organized into an integral circuit module. This system is used primarily for energy conservation and savings for residential, commercial, and industrial buildings and facilities. Sensor **1034** can be one of many varieties of space occupancy motion sensors. Such sensors can include, for example, optical incremental encoders, interrupters, photo-reflective sensors, proximity and Hall Effect sensors, laser interferometers, triangulation sensors, magnetostrictive sensors, ultrasonic sensors, cable extension sensors, LVDT sensors, and tachometer sensors. Occupancy motion sensor **1034** gets its power from the main power supply VAC **1020** or internally from LED lamp **1014**. On-board computer **1026** constantly runs a monitoring program that looks at the output of occupancy motion sensor **1034**. Power to LED array **1016** is normally on and will dim between a fully off zero percent to a preset intensity of less than 100 percent depending on the output of occupancy motion sensor **1034**. When occupancy motion sensor **1034** no longer detects the motion of presence of a person within its operating range, it flags an input to computer **1026**, which signals dimmer **1030** to dim the power to LED array **1016**. LED array **1016** can be programmed to dim instantaneously or after some pre-programmed time delay.

[0498] FIG. 75B shows an embodiment of the present invention, in particular shown as a schematic block diagram of an LED lamp **1038** that includes an LED array **1040** comprising a plurality of LEDs positioned in an elongated translucent tube **1042**. LED array **1040** is connected to a power supply comprising a source of VAC power **1044** electrically connected to a ballast **1046**, which is external to tube **1042**. An electrical connection **1048A** positioned in tube **1042** is powered from ballast **1046** and transmits AC power to AC-DC power converter **1047**, which in turn transmits DC power to an on-off switch **1050** also positioned in tube **1042** by way of electrical connection **1048B**. Power from ballast **1046** can be either AC or DC voltage. In the case of DC power going into AC-DC power converter **1047**, DC power will continue to be sent to on-off switch **1050**.

Switch **1050** is electrically connected to LED array **1040** by electrical connection **1052**. LED array **1040** contains the necessary electrical components to further reduce the power transmitted by switch **1050** by way of electrical connection **1052** to properly drive the plurality of LEDs in LED array **1040**.

[0499] An external motion sensor **1054** positioned external to LED lamp **1038** is operationally connected to on-off switch **1050** by any of three optional alternative signal paths **1056A**, **1056B**, or **1056C**. Signal path **1056A** is an electrical signal line wire extending directly from sensor **1054** to switch **1050**. Signal path **1056B** is a wireless signal path shown in dash line extending directly to switch **1050**. Signal path **1056C** is a signal line wire that is connected to a PLC line **1058** that extends from VAC **1044** through tube **1042** to switch **1050**. Switch **1050** also contains the necessary electronics to decode the data information imposed on PLC line **1058** via signal path **1056C**. When sensor **1054** detects motion in the illumination area of LED array **1040**, sensor **1054** sends a signal to switch **1050** by way of signal path **1056A** or signal path **1056B** or signal path **1056C**, whatever the case may be, wherein switch **1050** is activated from the off mode to the on mode, so that power is transmitted through switch **1050** to LED array **1040** and LED array **1040** illuminates the area. At such time sensor **1054** no longer detects motion in the illumination area of LED array **1040**, sensor **1054** sends a signal to switch **1050** wherein switch **1050** is activated from the on mode to the off mode, so that power to LED array **1040** is terminated and LED array **1040** no longer illuminates the area.

[0500] FIG. 75C shows another embodiment of the present invention, in particular shown as a schematic block diagram of an LED lamp **1060** that includes an LED array **1062** comprising a plurality of LEDs positioned in a translucent tube **1064**. LED array **1062** is connected to a power supply comprising a source of VAC power **1066** electrically connected to a ballast **1068**, which is external to tube **1064**. An electrical connection **1070A** positioned in tube **1064** is powered from ballast **1068** and transmits AC power to AC-DC power converter **1069**, which in turn transmits DC power to a computer **1072** by way of electrical connection **1070B** and to dimmer **1076** by way of a similar electrical connection (not shown). Both computer **1072** and dimmer **1076** are also positioned in tube **1064**. Power from ballast **1068** can be either AC or DC voltage. In the case of DC power going into AC-DC power converter **1069**, DC power will continue to be sent to computer **1072** and dimmer **1076**. Computer **1072** is electrically and operatively connected by an electrical control connection **1074** to dimmer **1076**. An electrical connection **1078** connects dimmer **1076** to LED array **1062**. Dimmer **1076** will contain the necessary electronics needed to decode the data control signals sent by computer **1072**, and will provide the proper current drive power required to operate LED array **1062**. Single LED array **1062** controlled by dimmer **1076** can represent multiple LED arrays **1062** each correspondingly controlled by one of a plurality of dimmers **1076** (not shown), wherein the plurality of dimmers **1076** are each independently controlled by computer **1072**. Computer **1072** includes a microprocessor, a program installed therein, memory, input/output means, and addressing means.

[0501] An external motion sensor **1080** positioned external to LED lamp **1060** is operationally connected to com-

puter **1072** by any of three optional alternative signal paths **1082A**, **1082B**, or **1082C**. Signal path **1082A** is an electrical signal line wire extending directly from sensor **1080** to computer **1072**. Signal path **1082B** is a wireless signal path shown in dash line extending directly to computer **1072**. Signal path **1082C** is a signal line wire that is connected to a PLC line **1084** that extends from VAC **1066** through tube **1064** to computer **1072**. Computer **1072** also contains the necessary electronics to decode the data information imposed on PLC line **1084** via signal path **1082C**.

[0502] When sensor **1080** detects motion or the presence of a person in the illumination area of LED array **1062**, sensor **1080** sends a signal to the input port of computer **1072** by way of signal path **1082A**, or signal path **1082B**, or signal path **1082C**, whichever the case may be. Computer **1072** is activated to send or to continue to send a signal from the output port of computer **1072** by electrical line **1074** to dimmer **1076**, so that full power is transmitted through electrical line **1078** to LED array **1062** wherein LED array **1062** provides full illumination of the area.

[0503] When sensor **1080** ceases to detect motion or the presence of a person after a preset time period in the illumination area of LED array **1062**, sensor **1080** sends a signal to the signal input port of computer **1072** by way of one of signal paths **1082A**, **1082B**, or **1082C**, whichever the case might be, whereby computer **1072** sends a signal from the computer signal output port to dimmer **1076** by electrical line **1074** wherein dimmer **1076** reduces power being sent by electrical line **1078** to LED array **1062** by a preset amount, so that LED array **1062** reduces full illumination of the area, that is, illumination is continued, but reduced to a lower illumination output level preset in dimmer **1076** or computer **1072**.

[0504] FIG. 76 shows another embodiment of the present invention in particular a schematic block diagram of a network **1086** of two LED lamps **1086A** and **1086B** in general proximity. LED lamp **1086A** includes an LED array **1088A** positioned in a translucent tube **1090A** that is connected to a power supply comprising a source of VAC power **1092A** electrically connected to a ballast **1094A**, which is external to tube **1090A**. An electrical connection **1096A** connects ballast **1094A** to an AC-DC power converter **1095A**, which in turn provides DC power to occupancy motion sensor **1098A** and dimmer **1102A** both positioned in LED lamp **1086A**, that is, in tube **1090A** by way of electrical connections **1096B** and **1100A** respectively. Dimmer **1102A** is connected to LED array **1088A** by an electrical connection **1104A**. LED lamp **1086B** includes an LED array **1088B** positioned in a translucent tube **1090B** that is connected to a power supply comprising a source of VAC power **1092B** electrically connected to a ballast **1094B**, which is external to tube **1090B**. An electrical connection **1096C** connects ballast **1094B** to an AC-DC power converter **1095B**, which in turn provides DC power to occupancy motion sensor **1098B** and dimmer **1102B** both positioned in LED lamp **1086B**, that is, in tube **1090B** by way of electrical connections **1096D** and **1100B** respectively. Dimmer **1102B** is connected to LED array **1088B** by an electrical connection **1104B**. LED arrays **1088A** and **1088B** can each include either a plurality of LEDs or a single LED. The number of individual LEDs in each LED array **1088A** and **1088B** can differ. Likewise, dimmers **1102A** and **1102B** can represent a

plurality of dimmers **1102A** and **1102B**, each controlling individual LEDs arrays **1088A** and **1088B** respectively.

[0505] An external central computer **1106** shown positioned between LED lamps **1086A** and **1086B** is in network signal communication with sensors **1098A** and **1098B**, and ultimately with dimmers **1102A** and **1102B**, respectively. Sensor **1098A** sends a sensor data output signal by wire signal path **1108X** or alternative wireless signal path **1108Y** as shown by dash line to computer **1106**; and sensor **1098B** sends a sensor data output signal by wire signal path **1110X** or alternative wireless signal path **1110Y** as shown by dash line to computer **1106**. In programmed response to the sensor signals, computer **1106** sends a computer data output signal by wire signal path **1112X** or alternative wireless signal path **1112Y** as shown by dash line to control dimmer **1102A**; and computer **1106** also sends a computer data output signal by wire signal path **1114X** or alternative wireless signal path **1114Y** as shown by dash line to control dimmer **1102B**. Dimmers **1102A** and **1102B** both contain the electronics needed to decode the data control signals sent by computer **1106**, and will provide the proper current drive power required to operate LED arrays **1088A** and **1088B** respectively. Computer **1106** includes a microprocessor, a program installed therein, memory, input/output means, and addressing means.

[0506] Computer **1106** continuously compares the sensor data signals received in accordance with a computer monitoring program and transmits computer signals to dimmers **1102A** and **1102B** in accordance with a computer program, so as to control the current output of dimmers **1102A** and **1102B**, so as to prevent flickering of LED lamps **1086A** and **1086B**. Thus signaling dimmers **1102A** and **1102B** either to maintain full power to LED arrays **1088A** and **1088B** in accordance with preset power reductions, so that LED arrays **1088A** and **1088B** emit full capacity light, or on the other hand to reduce power after a set time delay to LED arrays **1088A** and **1088B** with the result that as a person walks about the illumination areas of LED lamps **1086A** and **1086B**, both lamps emit the same less than full capacity illumination with the result that continuous flickering caused by different power controls at dimmers **1102A** and **1102B** is avoided. In summary, the operational networking of LED lamp network **1086** prevents flickering from occurring.

[0507] As indicated in FIGS. 76 and 76A, four combinations of signals from both sensors **1098A** and **1098B** to computer **1106** are possible. For purposes of elucidation herein, when motion is detected by sensors **1098A** and **1098B**, signals from the sensors are indicated by YES, and when no motion is detected by sensors **1098A** and **1098B**, negative signals from the sensors are indicated by NO. Computer **1106** is programmed to send computer control signals to dimmers **1102A** and **1102B** as a result of the received sensor signals. Full power at dimmers **1102A** and **1102B** is indicated by a plus sign (+) and reduced power to dimmers **1102A** and **1102B** is indicated by a minus sign (-).

[0508] The four combinations of sensor signals as received by computer **1106** are shown in FIG. 76A as follows:

[0509] 1. Sensor **1098A** does detect motion and sensor **1098B** also does detect motion wherein computer **1106** sends a computer signal (+) to both dimmers **1102A** and **1102B** to maintain full power to LED arrays **1088A** and **1088B** respectively.

[0510] 2. Sensor 1098A does not detect motion and sensor 1098B does detect motion wherein computer 1106 sends a computer signal (−) to dimmer 1102A to reduce full power to LED array 1088A, and a computer signal (+) to dimmer 1102B to maintain full power to LED array 1088B.

[0511] 3. Sensor 1098A does detect motion and sensor 1098B does not detect motion wherein computer 1106 sends a computer signal (+) to dimmer 1102A to maintain full power to LED array 1088A, and a computer signal (−) to dimmer 1102B to reduce full power to LED array 1088B.

[0512] 4. Sensor 1098A does not detect motion and sensor 1098B does not detect motion wherein computer 1106 sends a computer signal (−) to both dimmers 1102A and 1102B to reduce full power to LED arrays 1088A and 1088B respectively in accordance with preset power reduction settings.

[0513] FIG. 77 shows another embodiment of the present invention in particular schematic block diagram of a network 1116 of two LED lamps including first and second LED lamps, namely, LED lamp 1116A and LED lamp 1116B, respectively, in general proximity. First LED lamp 1116A includes an LED array 1118A positioned in a translucent tube 1120A that is connected to a power supply comprising a source of VAC power 1122A electrically connected to a ballast 1124A, which is external to tube 1120A. An electrical connection 1126A connects ballast 1124A to an AC-DC power converter 1125A, which in turn provides DC power by way of electrical connection 1126B to a computer 1128A, an occupancy motion sensor 1130A, a timer 1134A, and dimmer 1138A all positioned within tube 1120A, that is, LED lamp 1116A. Occupancy motion sensor 1130A sends signals to computer 1128A by a signal path 1132A. Optional timer 1134A sends signals to computer 1128A by signal path 1136A. Computer 1128A sends programmed activation signals to dimmer 1138A by electrical connection 1140A. Dimmer 1138A contains the electronics needed to decode the data control signals sent by computer 1128A, and will provide the proper current drive power required to operate LED array 1118A. Dimmer 1138A transmits power to LED array 1118A by an electrical connection 1141A. Computer 1128A includes a microprocessor, a program installed therein, memory, input/output means, and addressing means. Second LED lamp 1116B includes an LED array 1118B positioned in a translucent tube 1120B that is connected to a power supply comprising a source of VAC power 1122B electrically connected to a ballast 1124B, which is external to tube 1120B. An electrical connection 1126C connects ballast 1124B to an AC-DC power converter 1125B, which in turn provides DC power by way of electrical connection 1126D to a computer 1128B, an occupancy motion sensor 1130B, a timer 1134B, and dimmer 1138B all positioned within tube 1120B, that is, LED lamp 1116B. Occupancy motion sensor 1130B sends signals to computer 1128B by a signal path 1132B. Optional timer 1134B sends signals to computer 1128B by signal path 1136B. Computer 1128B sends programmed activation signals to dimmer 1138B by electrical connection 1140B. Dimmer 1138B contains the electronics needed to decode the data control signals sent by computer 1128B, and will provide the proper current drive power required to operate LED array 1118B. Dimmer 1138B transmits power to LED array 1118B by an electrical connection 1141B. Computer 1128B includes a microprocessor, a program installed therein, memory, input/output means, and addressing means.

[0514] Computers 1128A and 1128B are in network signal communication with sensors 1130A and 1130B, respectively, and ultimately with dimmers 1138A and 1138B, respectively. Sensor 1130A sends data output signals to computer 1128A by signal path 1132A, and sensor 1130B sends data output signals to computer 1128B by signal path 1132B. In programmed response to the signals from sensor 1130A, computer 1128A sends computer data out communication signals 1142 by wire signal path 1144X or alternative wireless signal path 1144Y as shown by dash line or by PLC signal path 1144Z, any one signal path by itself or in combination with any other input communication signal path to the data in 1146 of computer 1128B. Simultaneously in programmed response to the signals from sensor 1130B, computer 1128B sends computer data out communication signals 1148 by wire signal path 1150X or alternative wireless signal path 1150Y as shown by dash line or by PLC signal path 1150Z, any one signal path by itself or in combination with any other input communication signal path to the data in 1152 of computer 1128A.

[0515] Computers 1128A and 1128B continuously process the sensor data signals from both sensors 1130A and 1130B received in accordance with a computer monitoring program and transmit resultant computer signals to dimmers 1138A and 1138B in accordance with the computer program, so as to control the current output of dimmers 1138A and 1138B, so as to prevent flickering of LED lamps 1116A and 1116B by 1) simultaneously signaling both dimmers 1138A and 1138B either to maintain full power and emit maximum light output, or 2) simultaneously signaling both dimmers 1138A and 1138B to reduce power by a preset amount and emit less than maximum light by a preset amount with the result that as a person walks about the combined illumination area of LED lamps 1116A and 1116B, both lamps emit the same illumination with the result that continuous flickering between the lamps caused by different power controls at dimmers 1138A and 1138B is avoided. In summary, the operational networking of LED lamp network 1116 creates a continuous identical illumination, so that flickering is prevented.

[0516] Four combinations of signals from both sensors 1030A and 1030B to computers 1128A and 1128B are possible. The four combinations of sensor signals as received by computers 1128A and 1128B, which are analogous to those shown in FIG. 76A, are as follows:

[0517] 1. Sensor 1030A does detect motion and sensor 1030B also does detect motion wherein computers 1128A and 1128B both send a computer signal (+) to both dimmers 1138A and 1138B to maintain full power to LED arrays 1118A and 1118B respectively.

[0518] 2. Sensor 1030A does not detect motion and sensor 1030B does detect motion wherein computer 1128A sends a computer signal (−) to dimmer 1138A to reduce full power to LED array 1118A, and computer 1128B sends a computer signal (+) to dimmer 1138B to maintain full power to LED array 1118B.

[0519] 3. Sensor 1030A does detect motion and sensor 1030B does not detect motion wherein computer 1128A sends a computer signal (+) to dimmer 1138A to maintain full power to LED array 1118A, and computer 1128B sends a computer signal (−) to dimmer 1138B to reduce full power to LED array 1118B.

[0520] 4. Sensor 1098A does not detect motion and sensor 1098B does not detect motion wherein computers 1128A and 1128B both send a computer signal (–) to both dimmers 1138A and 1138B to reduce full power to LED arrays 1118A and 1118B respectively in accordance with preset power reduction settings.

[0521] LED arrays 1118A and 1118B can each include either a plurality of LEDs or a single LED. The number of individual LEDs in each LED array 1118A and 1118B can differ. Likewise, dimmers 1138A and 1138B can represent a plurality of dimmers 1138A and 1138B, each controlling individual LED arrays 1118A and 1118B respectively.

[0522] Optional timer 1134A can be preset to self-activate in various modes. Timer 1134A can be preset to send a signal to computer 1128A to reduce or increase power to dimmer 1138A to a preset amount at a preset time by sending a timer signal by signal path 1136A to computer 1128A. For example, timer 1134A can be preset to activate a power reduction signal to computer 1128A at 10 PM. Timer 1134A can also be preset to activate a normal power turn on signal to computer 1128A at 8 AM. Likewise optional timer 1134B can be preset to self-activate in various modes. Timer 1134B can be preset to send a signal to computer 1128B to reduce or increase power to dimmer 1138B to a preset amount at a preset time by sending a timer signal by signal path 1136B to computer 1128B. For example, timer 1134B can be preset to activate a power reduction signal to computer 1128B at 10 PM. Timer 1134B can also be preset to activate a normal power turn on signal to computer 1128B at 8 AM.

[0523] It is possible to preset timers 1134A and 1134B at the same preset power reduction and normal power on modes and at the same preset time modes. It is also possible to preset timers 1134A and 1134B at different preset power reduction modes and different preset time modes. For example, timer 1134A could be set to send a 50 percent power reduction signal to computer 1128A at 10 PM and set to send a full power on mode signal to computer 1128A at 8 AM. At the same time, timer 1134B could be set to send a 50 percent power reduction signal to computer 1128B at 8 PM and set to send a full power on mode signal to computer 1128B at 7 AM.

[0524] FIG. 78 shows another embodiment of the present invention in particular a schematic block diagram of a network 1154 of two LED lamps including first and second LED lamps, namely, LED lamp 1156A and LED lamp 1156B, respectively, in general proximity. LED lamp 1156A includes an LED array 1158A positioned in a translucent tube 1160A that is connected to a power supply comprising a source of VAC power 1162A electrically connected to a ballast 1164A, which is external to tube 1160A. An electrical connection 1166A connects ballast 1164A to an AC-DC power converter 1165A, which in turn provides DC power to occupancy motion sensor 1168A and on-off switch 1172A both positioned in LED lamp 1156A, that is, in tube 1160A by way of electrical connections 1166B and 1170A respectively. Switch 1172A is connected to LED array 1158A by an electrical connection 1174A. LED lamp 1156B includes an LED array 1158B positioned in a translucent tube 1160B that is connected to a power supply comprising a source of VAC power 1162B electrically connected to a ballast 1164B, which is external to tube 1160B. An electrical connection 1166C connects ballast 1164B to an AC-DC power converter

1165B, which in turn provides DC power to occupancy motion sensor 1168B and on-off switch 1172B both positioned in LED lamp 1156B, that is, in tube 1160B by way of electrical connections 1166D and 1170B respectively. Switch 1172B is connected to LED array 1158B by an electrical connection 1174B.

[0525] A logic array 1176 is positioned between LED lamp 1156A and LED lamp 1156B. Logic array 1176 is an arrangement of electronically controlled switches, but can be constructed from relays, diodes, transistors, and optical elements that outputs a signal when specified input conditions are met.

[0526] When sensor 1168A detects motion in the illumination area of LED lamp 1156A, sensor 1168A sends a sensor output signal to logic array 1176 by a wire signal path 1180AX or alternatively by a wireless signal path 1180AY. In the same manner, when sensor 1168B detects motion in the illumination area of LED lamp 1156B, sensor 1168B sends a sensor output signal to logic array 1176 by a wire signal path 1180BX or alternatively by a wireless signal path 1180BY.

[0527] The logic circuit of logic array 1176 continuously processes output signals received from sensors 1168A and 1168B with the result that logic array 1176 sends a logic input signal to switch 1172A by a logic wire signal path 1184AX or by a logic wireless signal path 1184AY. Likewise, the logic circuit of logic array 1176 continuously processes output signals received from sensors 1168A and 1168B with the result that logic array 1176 also sends a logic input signal to switch 1172B by a logic wire signal path 1184BX or by an alternative logic wireless signal path 1184BY.

[0528] Four combinations of signals from both sensors 1168A and 1168B to logic array 1176 are possible. The four combinations of sensor signals as received by logic array 1176, which are analogous to those shown in FIG. 76A, are as follows:

[0529] 1. Sensor 1168A does detect motion and sensor 1168B also does detect motion wherein logic array 1176 sends a logic signal (+) to both switches 1172A and 1172B to maintain full power to LED arrays 1158A and 1158B respectively.

[0530] 2. Sensor 1168A does not detect motion and sensor 1168B does detect motion wherein logic array 1176 sends a logic signal (–) to switch 1172A to reduce full power to LED array 1158A, and a logic signal (+) to switch 1172B to maintain full power to LED array 1158B.

[0531] 3. Sensor 1168A does detect motion and sensor 1168B does not detect motion wherein logic array 1176 sends a logic signal (+) to switch 1172A to maintain full power to LED array 1158A, and a logic signal (–) to switch 1172B to reduce full power to LED array 1158B.

[0532] 4. Sensor 1168A does not detect motion and sensor 1168B does not detect motion wherein logic array 1176 sends a logic signal (–) to both switches 1172A and 1172B to reduce full power to LED arrays 1158A and 1158B respectively in accordance with preset power reduction settings.

[0533] FIG. 78A shows another embodiment of the present invention in particular schematic block diagram of a

network 1186 of two LED lamps including first and second LED lamps, namely, LED lamp 1186A and LED lamp 1186B, respectively, in general proximity. First LED lamp 1186A includes an LED array 1188A positioned in a translucent tube 1190A that is connected to a power supply comprising a source of VAC power 1192A electrically connected to a ballast 1194A, which is external to tube 1190A. An electrical connection 1196A connects ballast 1194A to an AC-DC power converter 1195A, which in turn provides DC power by way of electrical connection 1196B to a logic array 1198A, an occupancy motion sensor 1200A, a timer 1204A, and dimmer 1208A all positioned within tube 1190A, that is, LED lamp 1186A. Occupancy motion sensor 1200A sends signals to logic array 1198A by a signal path 1202A. Optional timer 1204A sends signals to logic array 1198A by signal path 1206A. Logic array 1198A sends activation signals to dimmer 1208A by electrical connection 1210A. Dimmer 1208A contains the electronics needed to decode the data control signals sent by logic array 1198A, and will provide the proper current drive power required to operate LED array 1188A. Dimmer 1208A transmits power to LED array 1188A by an electrical connection 1211A. Logic array 1198A is an arrangement of electronically controlled switches, but can be constructed from relays, diodes, transistors, and optical elements that outputs a signal when specified input conditions are met. Second LED lamp 1186B includes an LED array 1188B positioned in a translucent tube 1190B that is connected to a power supply comprising a source of VAC power 1192B electrically connected to a ballast 1194B, which is external to tube 1190B. An electrical connection 1196C connects ballast 1194B to an AC-DC power converter 1195B, which in turn provides DC power by way of electrical connection 1196D to a logic array 1198B, an occupancy motion sensor 1200B, a timer 1204B, and dimmer 1208B all positioned within tube 1190B, that is, LED lamp 1186B. Occupancy motion sensor 1200B sends signals to logic array 1198B by a signal path 1202B. Optional timer 1204B sends signals to logic array 1198B by signal path 1206B. Logic array 1198B sends activation signals to dimmer 1208B by electrical connection 1210B. Dimmer 1208B contains the electronics needed to decode the data control signals sent by logic array 1198B, and will provide the proper current drive power required to operate LED array 1188B. Dimmer 1208B transmits power to LED array 1188B by an electrical connection 1211B. Logic array 1198B is an arrangement of electronically controlled switches, but can be constructed from relays, diodes, transistors, and optical elements that outputs a signal when specified input conditions are met.

[0534] Logic arrays 1198A and 1198B are in network signal communication with sensors 1200A and 1200B, respectively, and ultimately with dimmers 1208A and 1208B, respectively. Sensor 1200A sends data output signals to logic array 1198A by signal path 1202A, and sensor 1200B sends data output signals to logic array 1198B by signal path 1202B. In response to the signals from sensor 1200A, logic array 1198A sends data out communication signals 1212 by wire signal path 1214X or alternative wireless signal path 1214Y as shown by dash line or by PLC signal path 1214Z, any one signal path by itself or in combination with any other input communication signal path to the data in 1216 of logic array 1198B. Simultaneously in response to the signals from sensor 1200B, logic array 1198B sends data out communication signals 1218 by

wire signal path 1220X or alternative wireless signal path 1220Y as shown by dash line or by PLC signal path 1220Z, any one signal path by itself or in combination with any other input communication signal path to the data in 1222 of logic array 1198A.

[0535] Logic array 1198A and 1198B continuously process the sensor data signals from both sensors 1200A and 1200B received in accordance with a logic monitoring program and transmit resultant signals to dimmers 1208A and 1208B in accordance with the logic program, so as to control the current output of dimmers 1208A and 1208B, so as to prevent flickering of LED lamps 1186A and 1186B by 1) simultaneously signaling both dimmers 1208A and 1208B either to maintain full power and emit maximum light output, or 2) simultaneously signaling both dimmers 1208A and 1208B to reduce power by a preset amount and emit less than maximum light by a preset amount with the result that as a person walks about the combined illumination area of LED lamps 1186A and 1186B, both lamps emit the same illumination with the result that continuous flickering between the lamps caused by different power controls at dimmers 1208A and 1208B is avoided. In summary, the operational networking of LED lamp network 1186 creates a continuous identical illumination, so that flickering is prevented.

[0536] Four combinations of signals from both sensors 1200A and 1200B to logic arrays 1198A and 1198B are possible. The four combinations of sensor signals as received by logic arrays 1198A and 1198B, which are analogous to those shown in FIG. 76A, are as follows:

[0537] 1. Sensor 1200A does detect motion and sensor 1200B also does detect motion wherein logic arrays 1198A and 1198B both send a logic signal (+) to both dimmers 1208A and 1208B to maintain full power to LED arrays 1188A and 1188B respectively.

[0538] 2. Sensor 1200A does not detect motion and sensor 1200B does detect motion wherein logic array 1198A sends a logic signal (-) to dimmer 1208A to reduce full power to LED array 1188A, and logic array 1198B sends a logic signal (+) to dimmer 1208B to maintain full power to LED array 1188B.

[0539] 3. Sensor 1200A does detect motion and sensor 1200B does not detect motion wherein logic array 1198A sends a logic signal (+) to dimmer 1208A to maintain full power to LED array 1188A, and logic array 1198B sends a logic signal (-) to dimmer 1208B to reduce full power to LED array 1188B.

[0540] 4. Sensor 1200A does not detect motion and sensor 1200B does not detect motion wherein logic arrays 1198A and 1198B both send a logic signal (-) to both dimmers 1208A and 1208B to reduce full power to LED arrays 1188A and 1188B respectively in accordance with preset power reduction settings.

[0541] LED arrays 1188A and 1188B can each include either a plurality of LEDs or a single LED. The number of individual LEDs in each LED array 1188A and 1188B can differ. Likewise, dimmers 1208A and 1208B can represent a plurality of dimmers 1208A and 1208B, each controlling individual LED arrays 1188A and 1188B respectively.

[0542] Optional timer 1204A can be preset to self-activate in various modes. Timer 1204A can be preset to send a signal

to logic array **1198A** to reduce or increase power to dimmer **1208A** to a preset amount at a preset time by sending a timer signal by signal path **1206A** to logic array **1198A**. For example, timer **1204A** can be preset to activate a power reduction signal to logic array **1198A** at 10 PM. Timer **1204A** can also be preset to activate a normal power turn on signal to logic array **1198A** at 8 AM. Likewise optional timer **1204B** can be preset to self-activate in various modes. Timer **1204B** can be preset to send a signal to logic array **1198B** to reduce or increase power to dimmer **1208B** to a preset amount at a preset time by sending a timer signal by signal path **1206B** to logic array **1198B**. For example, timer **1204B** can be preset to activate a power reduction signal to logic array **1198B** at 10 PM. Timer **1204B** can also be preset to activate a normal power turn on signal to logic array **1198B** at 8 AM.

[0543] It is possible to preset timers **1204A** and **1204B** at the same preset power reduction and normal power on modes and at the same preset time modes. It is also possible to preset timers **1204A** and **1204B** at different preset power reduction modes and different preset time modes. For example, timer **1204A** could be set to send a 50 percent power reduction signal to logic array **1198A** at 10 PM and set to send a full power on mode signal to logic array **1198A** at 8 AM. At the same time, timer **1204B** could be set to send a 50 percent power reduction signal to logic array **1198B** at 8 PM and set to send a full power on mode signal to logic array **1198B** at 7 AM.

[0544] FIG. 79A shows an electrical circuit **1256** for providing power to four LED arrays **1258** that is essentially the same as the electrical circuits shown in FIGS. 4, 14, 53, and 63 described hereinbefore. The circuit module shown is a by-pass or feed-thru circuit that simply passes the voltage to LED arrays **1258**. The hardware for the by-pass or feed-thru circuit module can consist of straight electrical conductors or headers with jumpers installed. The combination of the by-pass or feed-thru circuit module and LED array **1258** represents the LED lamp. AC voltage inputs of 200-300 volts and 0-4 volts are typical outputs from a rapid start fluorescent ballast (not shown). But the input can be any AC voltage including 120 volts, 240 volts, or 277 volts as present in line power voltages. A voltage suppressor **1262** is connected across the two input AC voltages. A reduced AC voltage is tied to a full bridge rectifier **1260** as a result of voltage suppressor **1262**. Bridge rectifier **1260** and voltage suppressor **1262** represent the AC to DC power converters as described herein as **869, 891, 917, 947, 977, 1003, 1023, 1047, 1069, 1095A, 1095B, 1125A, 1125B, 1165A, 1165B, 1195A, and 1195B**. The positive DC voltage output of bridge rectifier **1260** is connected to optional current limiting resistors **R2, R3, R4, and R5**. The other side of current limiting resistors **R2, R3, R4, and R5** are connected to the anode side of first LEDs **D1, D3, D5, and D7** respectively. The cathode side of first LEDs **D1, D3, D5, and D7** are in turn connected to the anode side of second LEDs **D2, D4, D6, and D8** respectively. The cathode side of second LEDs **D2, D4, D6, and D8** are in turn connected to the anode side of third LEDs in series (not shown). The cathode side of the last LED in each LED string is in turn connected to the negative DC voltage or ground output of bridge rectifier **1260**.

[0545] FIG. 79B shows an alternative electrical circuit **1264** for four parallel LED arrays **1266** analogous to that

shown in FIG. 79A for providing power to a plurality of LEDs. The AC voltage inputs of 200-300 volts and 0-4 volts are typical outputs from a rapid start fluorescent ballast, but the input can be any AC voltage including 120 volts, 240 volts, or 277 volts as present in line power voltages. A capacitor **1268** is used to drop the line input voltage and a small resistor **R1** is used to limit the inrush current to the circuit. A larger capacitor **C** will increase the current into the circuit and a smaller one will reduce it. Capacitor **1268** must be a non-polarized type with a voltage rating of 200 volts or more. The value of capacitor **1268** can range from 1 uF to 4 uF for adequate current to drive LED arrays **1266**. A voltage absorber (ZNR), movistor (MOV), or varistor (V) is used to suppress the voltage on the other side of capacitor **1268** to within a lower workable AC voltage, and is interchangeable with voltage suppressor **1262** described in FIG. 79A. Since the capacitor **1268** must pass current in both directions, a diode and in particular, a zener diode **Z** is connected in parallel with voltage suppressor **V** to provide a path for the negative half cycle. The zener diode **Z** serves as a regulator and provides a path for the negative half cycle current when it conducts in the forward direction. A power rated diode or similar rectifier can be used in place of zener diode **Z** to produce similar results. A voltage suppressor **V** is connected across the two input AC voltages. The reduced AC voltage is tied to full bridge rectifier **1270**. Bridge rectifier **1270** and voltage suppressor **V** represent the AC to DC power converters as described herein as **869, 891, 917, 947, 977, 1003, 1023, 1047, 1069, 1095A, 1095B, 1125A, 1125B, 1165A, 1165B, 1195A, and 1195B**. The positive DC voltage output of bridge rectifier **1270** is connected to optional current limiting resistors **R2, R3, R4, and R5**. There can be more LED strings in parallel (not shown). The other side of current limiting resistors **R2-R5** are each connected to the anode side of first LEDs **D1, D3, D5, and D7** of LED arrays **1266**, respectively. The cathode side of first LEDs **D1, D3, D5, and D7** are connected to the anode side of second LEDs **D2, D4, D6, and D8**, of LED arrays **1266**, respectively. The cathode side of second LEDs **D2, D4, D6, and D8** are connected to the anode side of third LEDs in series (not shown). The cathode side of the last LED in each LED string is connected to the negative DC voltage or ground output of bridge rectifier **1270**. An optional filter capacitor **1272** can be used in parallel with the LED strings across the DC voltage leads to absorb the surge that passes through the capacitor **1268**. Most LEDs will operate more efficiently with filter capacitor **1272** installed.

[0546] It should be noted that even though one electronic component consisting of a capacitor, a voltage suppressor, a diode, a bridge rectifier, etc. is shown in either one or both FIGS. 79A and 79B, more than one electronic component of each type herein described can be used in the final design of the present LED lamp.

[0547] In addition, in standalone LED lamps of the present invention using computers, a self-contained program stored in the computer operates the current driver outputs of each dimmer controlling each LED array depending on the condition of the sensor and timer outputs. In the network systems of FIGS. 77 and 78A, there are shown three optional alternative methods of providing external data communications to the individual computers or logic arrays contained in each LED lamp of the present invention. An external and remote data control signal can be imposed on the power line to provide instructions to computer to operate

the current driver outputs of dimmer to control the LED arrays. The data input can be connected to one of many varieties of external control consoles including a PC, wall mounted keypad, PDA, etc. An on-board computer constantly runs a monitoring program that looks at the PLC data input line or wireless data communications input line or direct hard-wired data line. Power to the LED array is normally on and will go off or dim to a certain intensity depending on the data input control instructions. The data input control instructions can tell the on-board computer to turn the LED arrays on or off or set the output of the LED arrays at various dimming levels as desired by the user.

[0548] It should be noted that a network of similarly configured plurality of LED lamps of the present invention as described in **FIGS. 73 through 78A** can be combined to form a complete intelligent system. Any one LED lamp can be set as a master and all other LED lamps in the network can be set up as slaves. For example, the sensor input of all LED lamps can be monitored as a whole and as long as one occupancy motion detector senses the presence of a person, all LED lamps will remain on. Only after all occupancy motion detectors acknowledge that no one is in the occupied space will all or some of the LED lamps go off or go dim to a certain preset level. The use of an on-board computer offers the flexibility to perform various operational tasks, although logic gate arrays will work as well.

[0549] Other embodiments or modifications may be suggested to those having the benefit of the teachings therein, and such other embodiments or modifications are intended to be reserved especially as they fall within the scope and spirit of the subjoined claims.

What is claimed is:

1. A light emitting diode (LED) lamp for mounting to an existing fixture for a fluorescent lamp having a ballast assembly including ballast opposed electrical contacts, comprising:

a tube having tube ends,

at least one LED positioned within said tube between said tube ends,

electrical circuit means for providing electrical power from the ballast assembly to said at least one LED,

means for electrically connecting said electrical circuit means with the ballast opposed electrical contacts,

said electrical circuit means including an LED electrical circuit including at least one electrical string positioned within said tube and generally extending between said tube ends, said at least one LED being in electrical connection with said at least one electrical string,

said at least one LED being positioned to emit light through said tube,

means for supporting and holding said at least one LED and said LED electrical circuit,

means for suppressing ballast voltage being delivered from the ballast assembly, said means for suppressing ballast voltage being in electrical connection with said electrical circuit means, and

means for controlling the delivery of said electrical power from said ballast assembly to said at least one LED.

2. The LED lamp in accordance with claim 1, wherein said means for controlling includes an on-off switch positioned in said LED lamp on said electrical circuit in operative association with said at least one LED, said switch being operable between an on mode wherein electrical power is delivered to said at least one LED and an off mode wherein said electrical power is not delivered to said at least one LED.

3. The LED lamp in accordance with claim 2, further including a manual control unit positioned external to said tube in signal communication with said switch, said manual control unit being manually operable between an activation mode wherein a control signal is sent to said switch to activate said switch to said on mode and a deactivation mode wherein a control signal is sent to said switch to deactivate said switch to said off mode.

4. The LED lamp in accordance with claim 3, further including a control signal path from said manual control unit to said switch.

5. The LED lamp in accordance with claim 4, wherein said control signal path comprises a control signal line wire.

6. The LED lamp in accordance with claim 4, wherein said control signal path comprises a wireless signal.

7. The LED lamp in accordance with claim 4, further including an external source of AC power and a PLC line connecting said source of AC power with said switch, and wherein said control signal path comprises a control signal line wire connected to said PLC line.

8. The LED lamp as set forth in claim 2, wherein said means for controlling includes a timer positioned in said tube in operative signal association with said switch.

9. The LED lamp as set forth in claim 8, further including a manual timer control unit positioned external to said tube in operative signal association with said timer, said manual timer control unit being manually controllable to signal set times to signal said switch to activate to said on mode and to deactivate to said off mode in accordance with said set times.

10. The LED lamp in accordance with claim 9, further including a control signal path from said manual timer control unit to said timer.

11. The LED lamp in accordance with claim 10, wherein said control signal path comprises a control signal line wire.

12. The LED lamp in accordance with claim 10, wherein said control signal path comprises a wireless signal.

13. The LED lamp in accordance with claim 10, further including an external source of AC power and a PLC line connecting said source of AC power with said timer, and wherein said control signal path comprises a control signal line wire connected to said PLC line.

14. The LED lamp in accordance with claim 9, said timer being preset to set times to signal said switch to activate said switch to said switch on mode and to deactivate said switch to said switch off mode in accordance with said set times.

15. The LED lamp in accordance with claim 2, further including an occupancy motion sensor in operative signal association with said switch wherein said sensor sends a signal to said switch to operate said switch to a closed mode when motion is detected in the illumination area of said LED lamp wherein power is transmitted to said LED array to illuminate and further wherein said sensor sends a signal to said switch to operate said switch to an open mode when motion is not detected in the illumination area of said LED

lamp wherein power is not transmitted to said LED array and illumination from said LED array ceases.

16. The LED lamp in accordance with claim 15, wherein said motion sensor is positioned within said lamp.

17. The LED lamp in accordance with claim 16, wherein said motion sensor is positioned external to said lamp.

18. The LED lamp in accordance with claim 17, further including a control signal path from said sensor to said switch.

19. The LED lamp in accordance with claim 18, wherein said control signal path comprises a control signal line wire.

20. The LED lamp in accordance with claim 18, wherein said control signal path comprises a wireless signal.

21. The LED lamp in accordance with claim 18, further including an external source of AC power and a PLC line connecting said source of AC power with said switch, and wherein said control signal path comprises a control signal line wire connected to said PLC line.

22. The LED lamp in accordance with claim 1, wherein said means for controlling includes a current driver dimmer positioned in said LED lamp and in operative signal and power association with said at least one LED, said dimmer being for regulating the amount of power provided by said electrical power to said at least one LED.

23. The LED lamp in accordance with claim 22, further including a computer positioned in said lamp in operative power and signal association with said dimmer wherein said computer includes computer controls for signaling said dimmer to regulate the degree of power input to said at least one LED to control the degree of illumination by said at least one LED.

24. The LED lamp in accordance with claim 23, wherein said computer controls include signaling said dimmer to reduce power sent to said at least one LED by a set amount.

25. The LED lamp in accordance with claim 23, wherein said computer controls include signaling said dimmer to provide full power to said at least one LED.

26. The LED lamp in accordance with claim 23, further including a manual control unit for signaling said computer to set power settings for said computer controls, said manual control unit being positioned external to said tube.

27. The LED lamp in accordance with claim 26, wherein said manual control unit is also for signaling said computer relating to preset times relating to activation of said power settings for said computer controls.

28. The LED lamp in accordance with claim 27, further including a control signal path from said manual control unit to said computer.

29. The LED lamp in accordance with claim 28, wherein said control signal path comprises a control signal line wire.

30. The LED lamp in accordance with claim 28, wherein said control signal path comprises a wireless signal.

31. The LED lamp in accordance with claim 28, further including an external source of AC power and a PLC line connecting said source of AC power with said computer, and wherein said control signal path comprises a control signal line wire connected to said PLC line.

32. The LED lamp in accordance with claim 23, further including a switch in operative signal control with said computer wherein operation of said switch activates said computer to regulate the degree of power input to said at least one LED to control the degree of illumination by said at least one LED.

33. The LED lamp in accordance with claim 32, said switch being positioned external to said tube.

34. The LED lamp in accordance with claim 33, further including a timer in operative signal connection with said switch for providing preset times of operating said switch to send signals to said computer to signal said dimmer to control the degree of power input to said at least one LED.

35. The LED lamp in accordance with claim 34, said timer being positioned external to said tube and being manually operable to set times for operation of said switch to signal said computer at preset times to operate said dimmer to regulate the degree of power input to said at least one LED.

36. The LED lamp in accordance with claim 35, further including a control signal path from said switch to said computer.

37. The LED lamp in accordance with claim 36, wherein said control signal path comprises a control signal line wire.

38. The LED lamp in accordance with claim 36, wherein said control signal path comprises a wireless signal.

39. The LED lamp in accordance with claim 36, further including an external source of AC power and a PLC line connecting said source of AC power with said computer, and wherein said control signal path comprises a control signal line wire connected to said PLC line.

40. The LED lamp in accordance with claim 34, wherein said timer and said switch are positioned within said tube, said timer being preset for times of operation of said switch between on and off modes for signaling said computer to operate said dimmer at preset times at preset degrees of power input to said at least one LED.

41. The LED lamp in accordance with claim 23, further including an occupancy motion sensor in operative signal connection with said computer.

42. The LED lamp in accordance with claim 41, said sensor being for signaling said computer upon detection of motion and upon lack of detection of motion in the illumination area of said at least one LED.

43. The LED lamp in accordance with claim 41, wherein said sensor is positioned within said tube.

44. The LED lamp in accordance with claim 41, wherein said sensor is positioned external to said tube.

45. The LED lamp in accordance with claim 44, further including a control signal path from said switch to said computer.

46. The LED lamp in accordance with claim 45, wherein said control signal path comprises a control signal line wire.

47. The LED lamp in accordance with claim 45, wherein said control signal path comprises a wireless signal.

48. The LED lamp in accordance with claim 45, further including an external source of AC power and a PLC line connecting said source of AC power with said computer, and wherein said control signal path comprises a control signal line wire connected to said PLC line.

49. The LED lamp in accordance with claim 43, including another LED lamp having another at least one LED positioned in another tube including other electrical power and another ballast assembly and other means for controlling the delivery of said other electrical power from said another ballast assembly to said another LED lamp, said another LED lamp further including another current driver dimmer in operative signal and power association with said another at least one LED, said another dimmer being positioned in said another tube, said another dimmer being for regulating the amount of power provided by said other electrical power

to said another at least one LED, said another LED lamp having another sensor positioned in said another tube, said another occupancy motion sensor being for detection of motion and lack of detection of motion in the illumination area of said another at least one LED.

50. The LED lamp in accordance with claim 49, wherein said computer and said another computer are in network signal communication with said sensor and with said another sensor, wherein sensor data signals received by said computer and by said another computer are continuously compared in accordance with a computer program, wherein said computer signals said dimmer and said another computer signals said another dimmer, and wherein the regulation of power outputs of said dimmer and said another dimmer to said at least one LED and said another at least one LED, respectively, are equal.

51. The LED lamp in accordance with claim 50, wherein the power outputs of said dimmer and said another dimmer are reduced to a less than full power output when both said sensor and said another sensor detect no occupancy motion and wherein the power outputs of both said dimmer and said another dimmer are increased to a full power output when either said sensor or said another sensor detect occupancy motion.

52. The LED lamp in accordance with claim 1, wherein said means for supporting and holding said at least one LED and said LED electrical circuit being positioned within said tube between said tube ends.

53. The LED lamp in accordance with claim 1, wherein said electrical circuit means for providing electrical power from the ballast assembly to said at least one LED includes at least one metal substrate circuit board.

54. The LED lamp in accordance with claim 53, further including means for supporting and holding said at least one LED and said LED electrical circuit, said means for supporting being said at least one metal substrate circuit board positioned within said tube between said tube wall ends.

55. The LED lamp in accordance with claim 1, wherein said at least one LED is a plurality of LEDs.

56. The LED lamp in accordance with claim 1, wherein said at least one LED is an OLED.

57. The LED lamp in accordance with claim 1, wherein said at least one LED is a high-brightness LED.

58. The LED lamp in accordance with claim 22, wherein said current driver dimmer is a plurality of current driver dimmers.

59. The LED lamp in accordance with claim 1, wherein said electrical circuit means further including at least one full wave bridge rectifier for converting AC voltage received from said ballast assembly to DC voltage.

60. The LED lamp in accordance with claim 59, further including at least one non-polarized capacitor in electrical series communication with said ballast opposed electrical contacts.

61. The LED lamp in accordance with claim 60, further including at least one resistor in electrical series communication with said ballast opposed electrical contacts.

62. The LED lamp in accordance with claim 61, further including at least one diode in electrical parallel communication with said ballast opposed electrical contacts.

63. The LED lamp in accordance with claim 62, wherein said at least one diode is at least one zener diode.

64. The LED lamp in accordance with claim 1, wherein said means for suppressing ballast voltage includes at least one voltage surge absorber (ZNR) in electrical parallel communication with said ballast opposed electrical contacts.

65. The LED lamp in accordance with claim 1, wherein said means for suppressing ballast voltage includes at least one movistor (MOV) in electrical parallel communication with said ballast opposed electrical contacts.

66. The LED lamp in accordance with claim 1, wherein said means for suppressing ballast voltage includes at least one varistor in electrical parallel communication with said ballast opposed electrical contacts.

67. The LED lamp in accordance with claim 1, further including at least one filter capacitor in parallel with said at least one LED electrical string.

68. The LED lamp in accordance with claim 23, wherein said computer is a timer positioned in said lamp in operative power and signal association with said dimmer.

69. The LED lamp in accordance with claim 8, wherein said timer is a computer positioned in said tube in operative signal association with said switch.

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