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(54) **Title**: LINEAR SOLID-STATE LIGHTING WITH VOLTAGE SENSING MECHANISM FREE OF FIRE AND SHOCK HAZARDS

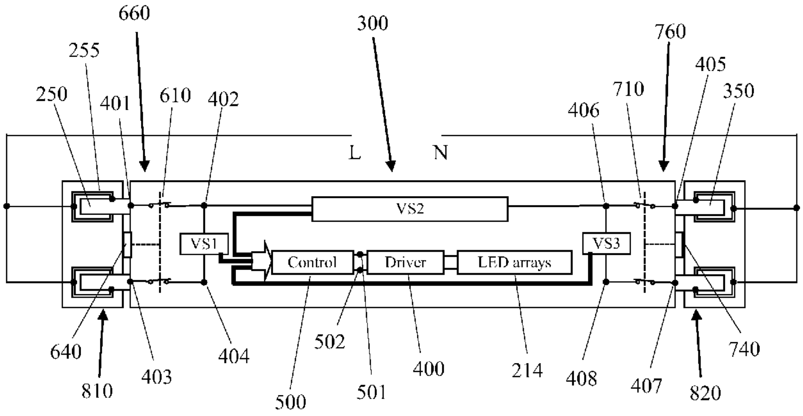

FIG. 8

(57) **Abstract**: A linear light-emitting diode (LED)-based solid-state lamp using a novel voltage sensing and control mechanism operates normally in both single-ended and double-ended luminaire fixtures. The voltage sensing and control mechanisms automatically detect supply source configuration in the fixture and make proper management so that the linear LED lamp works in any fixtures without operational uncertainty or risk of fire. When used with shock protection switches on the two lamp bases at two opposite ends, the universal lamp fully protects a person from possible electric shock during initial installation and re-lamping.

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LINEAR SOLID-STATE LIGHTING WITH VOLTAGE SENSING MECHANISM FREE OF FIRE AND SHOCK HAZARDS

TECHNICAL FIELD

This invention relates to linear light-emitting diode (LED) lamps that adopt novel voltage sensing and control mechanisms and thus work with any linear luminaire fixtures configured as single-ended or double-ended, and more particularly to a universal, shock and fire hazard-free linear LED tube lamp with a shock-protection mechanism.

BACKGROUND ART

Solid-state lighting from semiconductor light-emitting diodes (LEDs) has received much attention in general lighting applications today. Because of its potential for more energy savings, better environmental protection (with no hazardous materials used), higher efficiency, smaller size, and longer lifetime than conventional incandescent bulbs and fluorescent tubes, the LED-based solid-state lighting will be a mainstream for general lighting in the near future. Meanwhile, as LED technologies develop with the drive for energy efficiency and clean technologies worldwide, more families and organizations will adopt LED lighting for their illumination applications. In this trend, the potential safety concerns such as risk of electric shock and fire become especially important and need to be well addressed.

In a retrofit application of a linear LED tube (LLT) lamp to replace an existing fluorescent tube, one must remove the starter or ballast because the LLT lamp does not need a high voltage to ionize the gases inside the gas-filled fluorescent tube before sustaining continuous lighting. LLT lamps operating at the AC mains, such as 110, 220, and 277VAC, have one construction issue related to product safety and needed to be resolved prior to wide field deployment. This kind of LLT lamps always fails a safety test, which measures through lamp leakage current. Because the line and the neutral of the AC mains apply to both opposite ends of the tube when connected, the measurement of current leakage from one end to the other consistently results in a substantial current flow, which may present a risk of shock during re-lamping. Due to this potential shock risk to the person who replaces LLT lamps in an existing fluorescent tube fixture, Underwriters Laboratories (UL) uses its standard, UL 935, Risk of Shock During Relamping (Through Lamp), to do the current leakage test and to determine if LLT lamps under test meet the consumer safety requirement.

Appliances such as toasters and other appliances with exposed heating filaments present the same kind of hazard. When the line and the neutral wire reverse, the heating filaments can remain live even though the power switches to “off”. Another example is screw-in incandescent bulbs. With the line and the neutral wire reversed, the screw-in thread of the socket remains energized. These happen when the line and the neutral wires in the wiring behind the walls or in the hookup of sockets are somehow interchanged even with polarized sockets and plugs that are designed for safety. The reason why a consumer can widely use the appliances with heating filaments and screw-in light lamps without worrying about shock hazard is that they have some kinds of protections. The said appliances have protection grids to prevent consumers from touching the heating filaments even when they are cool. The screw-in light lamp receptacle has its two electrical contacts, the line and the neutral in proximity, recessed in the luminaire. When one screws an incandescent bulb in the receptacle, little shock risk exists.

As mentioned, without protection, shock hazard will occur for an LLT lamp, which is at least 2 feet long; it is very difficult for a person to insert the two opposite bi-pins at the two ends of the LLT lamp into the two opposite sockets at two sides of the luminaire fixture at the same time. Because protecting consumers from possible electric shock during re-lamping is a high priority for LLT lamp manufacturers, they need to provide a basic protection design strictly meeting the minimum leakage current requirement and to prevent any possible electric shock that users may encounter in actual usage, no matter how they instruct a consumer to install an LLT lamp in their installation instructions.

Referring to Figs. 1 and 2, a conventional LLT lamp **100** comprises a housing **110** with a length much greater than its diameter of 25 to 32 mm, two end caps **120** and **130** with bi-pins **180** and **190** respectively on two opposite ends of the housing **110**, LED arrays **140** mounted on a printed circuit board (PCB) **150**, and an LED driver **160** used to receive energy from the AC mains through electrical contacts **142** and the bi-pins **180** and **190**, to generate a proper DC voltage with a proper current, and to supply it to the LED arrays **140** such that the LEDs **170** on the PCB **150** can emit light. The bi-pins **180** and **190** on the two end caps **120** and **130** connect electrically to the AC mains, either 110 V, 220 V, or 277 VAC, through two electrical sockets located lengthways in an existing fluorescent tube fixture whereas the two sockets in the fixture connect electrically to the line and the neutral wire of the AC mains, respectively. This is a so called “double-ended” configuration.

To replace a fluorescent tube with an LLT lamp **100**, one inserts the bi-pin **180** at one end of the LLT lamp **100** into one of the two electrical sockets in the fixture and then inserts the other bi-pin **190** at the other end of the LLT lamp **100** into the other electrical socket in the fixture. When the line power of the AC mains applies to the bi-pin **180** through one socket, and the other bi-pin **190** at the other end has not yet been in the other socket in the fixture, the LLT lamp **100** and the LED driver **160** are deactivated because no current flows through the LED driver **160** to the neutral. However, the internal electronic circuitry is live. At this time, if the person who replaces the LLT lamp **100** touches the exposed bi-pin **190**, which is energized, he or she will get electric shock because the current flows to earth through his or her body—a shock hazard.

Almost all the LLT lamps currently available on the market are without any protections for such electric shock. The probability of getting shock is 50%, depending on whether the person who replaces the lamp inserts the bi-pin first to the line of the AC mains or not. If he or she inserts the bi-pin **180** or **190** first to the neutral of the AC mains, then the LLT lamp **100** is deactivated while the internal circuitry is not live—no shock hazard. An LLT lamp supplier may want to adopt single protection only at one end of an LLT lamp in an attempt to reduce the risk of shock during re-lamping. However, such a single protection approach cannot completely eliminate the possibility of shock risk. As long as shock risk exists, the consumer product safety remains the most important issue.

An easy solution to reducing the risk of shock is to connect electrically only one of two bi-pins at the two ends of an LLT lamp to the AC mains, leaving the other dummy bi-pin at the other end of the LLT lamp insulated, so called “single-ended”. In such a way, the line and the neutral of the AC mains go into the LLT lamp through the single-ended bi-pin, one for “line” (denoted as L, hereafter) and the other for “neutral” (denoted as N, hereafter). The electrically insulated dummy bi-pin at the other end only serves as a lamp holder to support LLT lamp mechanically in the fixture. In this case, however, the retrofit and rewiring of the existing fixture to enable such LLT lamp may involve two new electrical sockets replacement in the fixture and needs much longer time to complete the rewiring because conventional fluorescent tube is double-ended, and its fixture and lamp holder sockets are wired in a double-ended manner. The new sockets, rewiring, and installation costs together will be too high for consumers to replace conventional fluorescent tubes economically. Therefore, some manufacturers have modified the dummy bi-pin by internally connecting the two pins with a conductor. The purpose is to convert a double-ended fixture/wiring into a single-ended configuration so that the single-ended LLT lamp can be used in the double-ended fixture/wiring as shown in Fig. 3, no matter whether the active end of the LLT lamp is on the left or right hand side in the fixture.

In Fig. 3, the AC mains supply voltage to the bi-pin sockets in the lamp holder **311** and **312** from two opposite ends of the LLT lamp **101**-- a double-ended configuration. However, LLT lamp **101** is internally connected as single ended because two pins **181** and **182** of the bi-pin are at one end, from which the driver **400** receives energy to power LED arrays **214**. The conductors **255** in the sockets of the lamp holder **311** and **312** are used to connect the bi-pins to the AC mains through electrical contacts shown as dots. The “dot” notation will be used to indicate electrical contacts throughout the figures. In order to receive energy from both ends of a double-ended fixture so that such a single-ended LLT lamp can operate in the double-ended fixture, manufacturers interconnect the two pins **183** and **184** of the bi-pin at one end with a conductor **251** inside the lamp such that electric current can flow through the pin **183**, the conductor **251**, the pin **184**, and an electrical wire **252** to the pin **182** at the other end. The modification seems to work to operate the LLT lamp in the double-ended fixture and be able to pass UL leakage current test. But this introduces shock and fire hazards. Imagine what will happen if consumers insert this electrically shorted end to a real single-ended fixture that has L and N connections on the bi-pin socket. This definitely will burn the connections on the bi-pin, possibly causing fire, and trip the circuit breaker. Due to this potential shock and fire risk for this kind of LLT lamp modification used with an existing fluorescent tube fixture, UL requires that the lamp base bi-pin used for mechanical support only not be interconnected or connected to dead metal parts of the lamp base. Furthermore, such single-ended LLT lamps are subjected to the requirements in UL Isolation of Lamp Pins test, ensuring no indication of fire or risk of electric shock if manufacturers want their products to be UL certified.

Similar hazards occur for double-ended lamps. There are many double-ended lamps without shock-protection mechanisms on the linear LED lighting market. Such lamps will never pass UL leakage current test and present the shock risk during re-lamping, as mentioned above. In addition, such non-UL compliant LLT lamps have their bi-pins internally connected. In Fig. 4, the driver **400** receives energy from both bi-pin sockets in the lamp holders **313** and **314** at opposite ends of the LLT lamp **102** to power LED arrays **214**--a double-ended configuration. The two pins **181** and **182** at one end are internally interconnected with a conductor **253**. Similarly, the two pins **183** and **184** at the other end are internally interconnected with a conductor **254**. In this case, as long as either one electrical contact in the bi-pin sockets has a power, the LLT lamps can operate. Manufacturers do this modification just trying to make it easy for consumers to more easily retrofit their linear luminaire fixtures without considering that the same hazards as mentioned for the single-ended LLT lamps may occur if either one of such bi-pins is inserted into a powered socket in a single-ended fixture with single-ended wiring. Furthermore, because LLT lamps have a very long service life, consumers who do not know single-ended and double-ended configurations may try to install their LLT lamps in another fixture with unknown wiring configuration several years later while original installation/wiring instructions may not be found. In this case, there exist fire and shock hazards.

In the US patent No. 8,147,091, issued April 3, 2012, double shock protection switches are used in a double-ended LLT lamp to isolate its LED driver such that a leakage current flowing from a live bi-pin, through the LED driver, to an exposed bi-pin is eliminated without hazards. Fig. 5 and 6 illustrate an LLT lamp with such shock protection switches. The LLT lamp **200** has a housing **201**; two lamp bases **260** and **360**, one at each end of the housing **201**; two actuation mechanisms **240** and **340** of shock protection switches **210** and **310** in the two lamp bases **260** and **360**, respectively; an LED driver **400**; and LED arrays **214** on an LED PCB **205**.

Fig. 6 is a block diagram of an LLT lamp **200** with the protection switches **210** and **310**. The shock protection switch **210** comprises two electrical contacts **220** and **221** and one actuation mechanism **240**. Similarly, a shock protection switch **310** comprises two electrical contacts **320** and **321** and one actuation mechanism **340**. The electrical contact **220** in the protection switch **210** connects electrically to the bi-pin **250** that connects to the L wire of the AC mains, and the other contact **221** connects to one of the inputs **270** of the LED driver **400**. Similarly, the electrical contact **320** in the protection switch **310** connects electrically to the bi-pin **350** that connects to the N wire of the AC mains, and the other contact **321** connects to the other input **370** of the LED driver **400**. The switch is normally off. Only after actuated, will the switches turn “on” such that they connect the AC mains to the LED driver **400** that in turn powers the LED arrays **214**. Served as gate controllers between the AC mains and the LED driver **400**, the protection switches **210** and **310** connect the line and the neutral of the AC mains to the two inputs **270** and **370** of the driver **400**, respectively. If only one shock protection switch **210** is used at one lamp base **260**, and if the bi-pin **250** of this end happens to be first inserted into the live socket at one end of the fixture, then a shock hazard occurs because the shock protection switch **210** already allows the AC power to electrically connect to the driver **400** inside the LLT lamp when the bi-pin **250** is in the socket. Although the LLT lamp **200** is deactivated at the time, the LED driver **400** is live. Without the shock protection switch **310** at the other end of the LLT lamp **200**, the driver input **370** connects directly to the bi-pin **350** at the other end of the LLT lamp **200**. This presents a shock hazard. However, if the shock protection switch **310** is used in accordance with this application, the current flow to the earth continues to be interrupted until the bi-pin **350** is inserted into the other socket, and the protection switch **310** is actuated. The switch redundancy eliminates the possibility of shock hazard for a person who installs an LLT lamp in the existing fluorescent tube fixture.

Double shock protection switches used in a double-ended LLT lamp can be used to isolate its LED driver such that a leakage current flowing from a live bi-pin, through the driver, to an exposed bi-pin is eliminated without hazards. However, such lamps are non-operable because no power supplies to the driver when used with single-ended fixtures. Even worse, when the two adjacent pins of the bi-pin on either one of the two ends in the double-ended LLT lamp are abnormally interconnected, the lamps may present fire hazard as mentioned above. In the present invention, however, double shock protection switches are used in a universal single-ended or double-ended LLT lamp to isolate its voltage sensing mechanism such that the leakage current flowing from a live bi-pin, through the voltage sensing mechanism, to an exposed bi-pin is interrupted without hazards.

DISCLOSURE OF INVENTION

A linear light-emitting diode (LED)-based solid-state device comprising a housing served as a heat sink, an LED driver, an LED printed circuit board (PCB) with a plurality of LEDs as LED arrays, a lens, a novel voltage sensing mechanism, and a control mechanism, is used to replace a fluorescent tube in a retrofit or newly-made luminaire fixture that could be single-ended or double-ended. The novel voltage sensing and control mechanisms in such an LLT lamp can detect supply source configuration in the fixture and make proper and necessary management so that the LLT lamp can operate with either single-ended or double-ended wiring fixtures without operational uncertainty or risk of fire. Such mechanisms when used with shock protection switches on both ends of the LLT lamp can buffer the line and neutral of the AC mains to electrically connect to two inputs of the LED driver used to power LED arrays. Therefore, no line voltage or leakage current will possibly appear at or flow through the exposed bi-pin during initial installation or re-lamping, thus completely eliminating risk of fire and electric shocks.

BRIEF DESCRIPTION OF DRAWINGS

Fig. 1 is an illustration of a conventional LLT lamp.

Fig. 2 is a block diagram of a conventional LLT lamp.

Fig. 3 is an illustration of a single-ended LLT lamp with an electrically shorted end, installed in a double-ended fixture lamp holder.

Fig. 4 is an illustration of a double-ended LLT lamp with two electrically shorted ends, installed in a double-ended fixture lamp holder.

Fig. 5 is an illustration of an LLT lamp with shock protection switches.

Fig. 6 is a block diagram of an LLT lamp with shock protection switches.

Fig. 7 is an illustration of an LLT lamp adopting shock protection switches and voltage sensing and control mechanisms inside the lamp according to the present invention.

Fig. 8 is a block diagram of an LLT lamp according to the present invention, in which the lamp is installed in a double-ended fixture lamp holder.

Fig. 9 is a block diagram of an LLT lamp according to the present invention, in which the lamp is installed in a single-ended fixture lamp holder.

Fig. 10 is a preferred embodiment of a voltage sensing mechanism and a control mechanism with shock protection switches used in the present invention.

BEST MODE FOR CARRYING OUT THE INVENTION

Misapplications of power supply connections for LLT lamps that substitute for linear fluorescent lamps are the main causes of fire and electric shock hazards today, where the LLT lamps are incorrectly connected to a supply source, the lamp base is either inserted incorrectly into a lamp holder or inserted into a lamp holder not intended for the lamp, or a lamp is connected to lamp holders with supply connections that do not match the lamp configuration. All of these misapplications may result in fire and shock hazards.

To completely remove these hazards from LLT lamps, manufacturers need to ensure at first no electrically shorted ends in either single-ended or double-ended LLT lamps. For double-ended LLT lamps, double protection switches on both ends of the LLT lamps must be used without compromise. For single-ended LLT lamps, consumers may find them difficult to use because there is a chance that the LLT lamps cannot be lighted up after installation due to the fact that the lamp may be connected to a lamp holder that does not have supply connections. In this case, the consumers need to uninstall the lamp and reinstall it with the end exchanged to see if the lamp is operational. Whereas a linear luminaire fixture may be wired single- or double-ended, a linear lamp may be configured internally in the similar fashion. However, any incompatible combinations of the lamps and the fixtures lead to failure of operation. These kinds of operational uncertainty, inconvenience, and possible hazards may severely affect the willingness of the consumers to adopt LLT lamps.

For consumer safety and convenience, it is believed that a universal LLT is needed to operate without operational uncertainty and hazards when installed in either single-ended or double-ended linear luminaire fixtures during initial installation for a retrofit luminaire conversion or during lamp replacement when the above-mentioned misapplications may occur. From a manufacturer's perspective, a universal LLT lamp is essential not only in protecting consumers but also in helping simplify manufacturing processes and inventories.

In the present invention, a voltage sensing mechanism, a control mechanism, and double shock protection switches are incorporated into a universal LLT lamp that can work with single-ended or double-ended linear luminaire fixtures. Moreover, because leakage current flowing from a live bi-pin, through the voltage sensing mechanism, to an exposed bi-pin is interrupted by the double shock protection switches, the universal LLT lamp is fire and shock hazard-free. This is different from the lamp adopted in the US patent No. 8,147,091, which can only be used in double-ended fixtures. However, the lamp used in the present invention has a similar appearance even on switch actuation mechanisms that protrude the end caps, although the switches used inside the lamp are different.

Figs. 7-9 illustrate an LLT lamp according to the present invention. The universal LLT lamp **300** has a housing **601**; two lamp bases **660** and **760**, one at each end of the housing **601**; two actuation mechanisms **640** and **740** of shock protection switches **610** and **710** in the two lamp bases **660** and **760**, respectively; a voltage sensing mechanism (**VS1**, **VS2**, and **VS3**); a control mechanism **500**; an LED driver **400**; and LED arrays **214** on an LED PCB **205**.

Fig. 8 is a block diagram of an LLT lamp according to the present invention, in which the lamp is installed in a double-ended fixture lamp holder. The lamp bases **660** and **760** respectively use the bi-pins **250** and **350** to connect the AC mains to the LED driver **400** through the protection switch **610** and **710** normally in “off” state, the voltage sensing mechanism (**VS1**,**VS2**, and **VS3**), and the control mechanism **500**. When actuated (pressed in, twisted on, etc.), the actuation mechanisms **640** and **740** respectively actuate the protection switches **610** and **710** and turn on the connection between the AC mains and the voltage sensing mechanism that comprises three voltage sensing devices, **VS1**, **VS2**, and **VS3**, wherein **VS1** and **VS3** are two end voltage sensing devices and **VS2** is a middle voltage sensing device. The thick lines in Fig. 8 represent L and N wires and a control signal path, same in Fig. 9. When each of the voltage sensing devices **VS1**, **VS2**, and **VS3** detects a predetermined threshold voltage existed between its two inputs, it will send a control signal to the control mechanism **500** which in turn connects the AC mains from one of the voltage sensing devices, **VS1**, **VS2**, and **VS3**, which detects the predetermined threshold voltage, to the LED driver **400**. In Fig. 8, the fixture lamp holder sockets are connected as double-ended configuration. The protection switch **610** at the lamp base **660** is of double-pole single-throw type, which consists of one actuation mechanism **640** and two sets of electrical contacts, (**401**, **402**) and (**403**, **404**), with the electrical contacts **401** and **403** connecting individually to the two pins of the bi-pin **250**. Similarly, the shock protection switch **710** at the other lamp base **760** comprises one actuation mechanism **740** and two sets of electrical contacts, (**405**, **406**) and (**407**, **408)**, with the electrical contacts **405** and **407** connecting individually to the two pins of the bi-pin **350**. The three voltage sensing devices, **VS1**, **VS2**, and **VS3**, are used in between electrical contacts, **402** and **404**, **402** and **406**, and **406** and **408**, respectively.

When someone tries to install the universal lamp **300** in a double-ended fixture as in Fig. 8, he or she needs to first insert, for example, the lamp base **660** to the fixture lamp holder **810**. The actuation mechanism **640** is actuated to turn on both sets of electrical contacts on the shock protection switch **610**. The voltage sensing device **VS1** senses whether a voltage exists between its two inputs, the electrical contacts **402** and **404**. Because the fixture lamp holder sockets are connected in a double-ended manner, the electrical contacts **402** and **404** have the same electrical potential, and no control signal is sent to the control mechanism **500**, and thus no power is delivered to LED. At this time, because the lamp base **760** has not yet been inserted into the lamp holder **820**, the actuation mechanism **740** is not actuated. So the shock protection switch **710** remains “off”, disconnecting internal electricity to the exposed bi-pin **350**, and thus no leakage current can possibly flow—no shock hazard. When the person who does the installation further inserts the lamp base **760** into the lamp holder **820**, the actuation mechanism **740** is actuated, which turns on the protection switch **710** that in turn connects the bi-pin **350** to the electrical contacts **406** and **408**. Again, because the fixture lamp holder sockets are connected in a double-ended manner, the voltage sensing device **VS3** senses no voltage between its two inputs, the electrical contacts **406** and **408**, and sends no control signal to the control mechanism **500**. However, when the protection switch **710** is “on”, the voltage sensing device **VS2** becomes live, which can sense whether a voltage exists between its two inputs, the electrical contacts **402** and **406**. In this case, the voltage sensing device **VS2** senses a predetermined threshold voltage between the electrical contacts **402** and **406**, and then sends a control signal to the control mechanism **500** which turns on the AC mains connection and in turn powers the driver **400** through the electrical contacts **501** and **502** and lights up the LED arrays **214**.

Fig. 9 is a block diagram of an LLT lamp according to the present invention, in which the lamp is installed in a single-ended fixture sockets. When someone tries to install the universal lamp **300** in the single-ended fixture, he or she first inserts, for example, the lamp base **660** to the fixture lamp holder **910**. As mentioned, the actuation mechanism **640** is actuated to turn on both sets of electrical contacts on the shock protection switch **610**. The voltage sensing device **VS1** senses whether a voltage exists between the electrical contacts **402** and **404** that it connects. If the sockets of the fixture lamp holder **910** are connected to the AC mains, the voltage sensing device **VS1** senses that a predetermined threshold voltage exists between the electrical contacts **402** and **404**, and sends a control signal to the control mechanism **500**, which turns on the AC mains connection and in turn powers the driver **400** through the electrical contacts **501** and **502** and lights up the LED arrays **214**. On the other hand, if the sockets of the fixture lamp holder **920** rather than the lamp holder **910** are connected to the AC mains, no voltage exists between the electrical contacts **402** and **404**, and thus no control signal is sent to the control mechanism **500**. When the person who does the installation further inserts the lamp base **760** into the lamp holder **920**, the actuation mechanism **740** is actuated, which turns on the protection switch **710** that in turn connects the bi-pin **350** to the electrical contacts **406** and **408**. Thus, the voltage sensing device **VS3** senses the predetermined threshold voltage between the electrical contacts **406** and **408**, and sends a control signal to the control mechanism **500**, which turns on the AC mains connection and in turn powers the driver **400** through the electrical contacts **501** and **502** and lights up the LED arrays **214**. At the same time, when the protection switch **710** is "on", the voltage sensing device **VS2** senses no voltage between the electrical contacts **402** and **406**, and sends no control signal to the control mechanism **500**, as expected. Therefore, the voltage sensing mechanism, the control mechanism, and the shock protection mechanism adopted in this universal LLT lamp can work with either single-ended or double-ended fixtures free of operational uncertainty and fire and shock hazards.

For illustration purpose, shock protection switches **610** and **710** are both of contact type, which can be a snap switch, a push-button switch, a micro switch, or a rotary switch. In reality, the shock protection switch can be of a non-contact type, such as electro-mechanical, electromagnetic, optical, electro-optic, fiber-optic, infrared, or wireless based. Furthermore, the non-contact shock protection switch can be of a sensing type, having a proximity control or sensing range up to 8 mm.

Fig. 10 depicts a preferred embodiment of a voltage sensing mechanism and a control mechanism with shock protection switches according to the present invention. Essentially the voltage sensing mechanism (**VS1**, **VS2** and **VS3**) and the control mechanism **500** (in Fig. 8 and Fig. 9) are embodied in three relays **503**, **504**, and **505**. Each of the relays comprises a coil of wire as a voltage sensing device and a switch. The control mechanism **500** corresponds to the three switches **506**, **507**, and **508**, respectively actuated by the sensing devices **VS1**, **VS2** and **VS3**. In Fig. 10, the relay **503** comprises a coil of wire as the voltage sensing device **VS1** and the switch **506** that has two sets of electrical contacts (**1001**, **1002**) and (**1003**, **1004**)--a double pole single-throw type. The coil of wire is wrapped around a soft iron core wherein when a predetermined threshold voltage applies on the coil or a proper electric current passes through it, the coil generates a magnetic field that activates the switch **506** by actuating a mechanism that turn on the electrical contacts **1001** and **1002**, and **1003** and **1004**, respectively. Similarly, the relay **504** comprises a coil of wire as the voltage sensing device **VS2** and the switch **507** that has two sets of electrical contacts (**1005**, **1006**) and (**1007**, **1008**). The relay **505** comprises a coil of wire as the voltage sensing device **VS3** and the switch **508** that has two sets of electrical contacts (**1009**, **1010**) and (**1011**, **1012**). For each of relays **503**, **504** and **505**, one electrical contact of each set of the electrical contacts connects to one of the two inputs of the respective coil and the other electrical contact connects to one of the inputs **501** and **502** of the LED driver **400**.

The three voltage sensing devices **VS1**, **VS2**, and **VS3** connected in series are respectively connected to the electrical contacts, **404** and **402**, **402** and **406**, and **406** and **408**, in which the electrical contacts **404** and **402**, and **406** and **408** are parts of the shock protection switches **610** and **710**, respectively. When the actuation mechanism **640** on the shock protection switch **610** is actuated, the electrical contacts **403** and **401** are respectively connected to the electrical contacts **404** and **402**. Similarly, when the actuation mechanism **740** on the shock protection switch **710** is actuated, the electrical contacts **405** and **407** are respectively connected to electrical contacts **406** and **408**. Both the shock protection switches **610** and **710** are needed to prevent the leakage current to flow. For example, if the lamp base **760** does not have the shock protection switch **710**, then the leakage current can flow from the electrical contact **401** and **402** through VS2 and VS3 to electrical contacts **405** and **407**, which connect to the exposed bi-pin **350** if the electrical contact **401** is connected to L of the AC mains, and the lamp base **760** has not yet been inserted into the fixture lamp holder.

When both lamp bases **660** and **760** (in Fig. 8 and 9) are inserted into the fixture lamp holder sockets **810** and **820** (in Fig. 8) or **910** and **920** (in Fig. 9), all the voltage sensing devices **VS1**, **VS2**, and **VS3** operate, but one and only one of them detects a voltage between its two inputs. A predetermined threshold voltage applying on a coil (**503**, **504**, or **505**) will generate a magnetic field strong enough to actuate the switch in the relay to connect the associated electrical contacts. On the other hand, if a voltage less than the predetermined threshold voltage applies on the coil, the magnetic field generated will be too weak to actuate the switch in the relay to connect the associated electrical contacts. When the voltage sensing device **VS1** detects the predetermined threshold voltage from the AC mains, the relay **503** functions such that the two sets of electrical contacts (**1001**, **1002**) and (**1003**, **1004**) are electrically connected respectively. Thus, the AC mains are connected to the LED driver **400**, which in turn powers up the LED arrays **214**. Similarly for **VS2** and **VS3**, when they detect the predetermined threshold voltage from the AC mains, the relays **504** and **505** function such that their associated sets of electrical contacts (**1005**, **1006**) and (**1007**, **1008**), (**1009**, **1010**) and (**1011**, **1012**) are connected respectively. The switches **506**, **507**, and **508** in the relays **503**, **504**, and **505** constitute the control mechanism which connects the AC mains from one of three voltage sensing devices **VS1**, **VS2**, and **VS3** to the LED driver **400** to power up the LED arrays **214**. This embodiment has the advantages of being simple and also passive without pre-power to operate. Thus, it is easy to implement.

Although the above embodiment uses electromagnetic relays to implement both the voltage sensing mechanism and the control mechanism, they can be of solid-state type, without moving parts to perform switch function controlled by a control signal. The voltage sensing mechanism and the control mechanism can be of a non-relay type, implemented by an application-specific integrated circuit (ASIC), a field-programmable gate array (FPGA), or a microprocessor.

INDUSTRIAL APPLICABILITY

The linear light-emitting diode (LED)-based solid-state lamp with the voltage sensing and control mechanism of this invention can operate normally in both single-ended and double-ended luminaire fixtures and prevents electric shock and fire hazards during initial installation or re-lamping.

WHAT IS CLAIMED IS:

1. A linear light-emitting diode (LED) tube lamp, comprising:

a housing having two ends;

a light-emitting diode printed circuit board (LED PCB), the LED PCB having LED arrays fixed thereon;

an LED driver that powers the LED arrays on the LED PCB, the LED driver having two inputs;

a voltage sensing mechanism, comprising two end voltage sensing devices and a middle voltage sensing device connected in series with the two end voltage sensing devices;

a control mechanism, receiving and coupling voltage outputs from the two end voltage sensing devices and the middle voltage sensing device and electrically connecting to the two inputs of the driver; and

two lamp bases respectively connected to the two ends of the housing, each lamp base having a bi-pin with two pins protruding outwards, and a shock protection switch, wherein: when the shock protection switch is off, the bi-pin is not electrically connected with any one of the voltage sensing devices; when the bi-pin is inserted into a lamp socket, the shock protection switch is actuated to electrically connect the two pins of the bi-pin respectively with two inputs of one of the end voltage sensing devices.

2. The linear LED tube lamp of claim 1, wherein the shock protection switch of each of the lamp bases comprises:

two sets of electrical contacts, each set having at least two electrical contacts, one electrically connected to one of the two pins of the bi-pin and another electrically connected to one of the two inputs of the associated end voltage sensing device; and

at least one switch actuation mechanism having a front portion protruding outwards,

wherein when the front portion of the switch actuation mechanism is pressed in or twisted on by inserting the bi-pin of the lamp base into a lamp socket, the electrical contacts of each of the two sets of electrical contacts are electrically connected to actuate the shock protection switch.

3. The linear LED tube lamp of claim 1, wherein each of the three voltage sensing devices comprises a coil of wire, and the control mechanism comprises three switches, each switch including two sets of electrical contacts, each set having two electrical contacts, wherein the three coils of wire and the three switches are paired to form three relays respectively,

wherein one electrical contact of each set of electrical contacts connects to one of the two inputs of the coil of wire and the other electrical contact connects to one of the inputs of the LED driver; and wherein when a predetermined threshold voltage applies on the coil of wire, the switch is actuated to electrically connect the two electrical contacts in each set of electrical contacts.

4. The linear LED tube lamp of claim 1, wherein the voltage sensing mechanism and the control mechanism are of a non-relay type, implemented by an application-specific integrated circuit (ASIC), a field-programmable gate array (FPGA), or a microprocessor.

5. The linear LED tube lamp of claim 1, wherein the voltage sensing mechanism and the control mechanism are of a non-electromagnetic relay type.

6. The linear LED tube lamp of claim 5, wherein the voltage sensing mechanism and the control mechanism are of a solid-state relay type.

7. The linear LED tube lamp of claim 1, wherein each of the shock protection switches is of a contact type.

8. The linear LED tube lamp of claim 2, wherein each of the shock protection switches is a snap switch, a push-button switch, a micro switch, or a rotary switch.

9. The linear LED tube lamp of claim 1, wherein each of the shock protection switches is of a non-contact type.

10. The linear LED tube lamp of claim 9, wherein each of the shock protection switches is electro-mechanical, electromagnetic, optical, electro-optic, fiber-optic, infrared, or wireless based.

11. The linear LED tube lamp of claim 10, wherein each of the shock protection switches is of a sensing type, having a proximity control or sensing range up to 8 mm.

12. A linear light-emitting diode (LED) tube lamp, comprising:

a housing having two ends;

a light-emitting diode printed circuit board (LED PCB), the LED PCB having LED arrays fixed thereon;

an LED driver that powers the LED arrays on the LED PCB, the LED driver having two inputs;

a voltage sensing mechanism, comprising two end voltage sensing devices and a middle voltage sensing device connected in series with the two end voltage sensing devices;

a control mechanism, receiving and coupling voltage outputs from the two end voltage sensing devices and the middle voltage sensing device and electrically connecting to the two inputs of the driver; and two lamp bases respectively connected to the two ends of the housing, each lamp base having a bi-pin with two pins protruding outwards, the two pins of the bi-pin electrically connected respectively with two inputs of one of the end voltage sensing devices.

13. The linear LED tube lamp of claim 12, wherein each of the three voltage sensing devices comprises a coil of wire, and the control mechanism comprises three switches, each switch including two sets of electrical contacts, each set having two electrical contacts, wherein the three coils of wire and the three switches are paired to form three relays respectively,

wherein one electrical contact of each set of electrical contacts connects to one of the two inputs of the coil of wire and the other electrical contact connects to one of the inputs of the LED driver; and wherein when a predetermined threshold voltage applies on the coil of wire, the switch is actuated to electrically connect the two electrical contacts in each set of electrical contacts.

14. The linear LED tube lamp of claim 12, wherein the voltage sensing mechanism and the control mechanism are of a non-relay type, implemented by an application-specific integrated circuit (ASIC), a field-programmable gate array (FPGA), or a microprocessor.

15. The linear LED tube lamp of claim 12, wherein the voltage sensing mechanism and the control mechanism are of a non-electromagnetic relay type.

16. The linear LED tube lamp of claim 15, wherein the voltage sensing mechanism and the control mechanism are of a solid-state relay type.

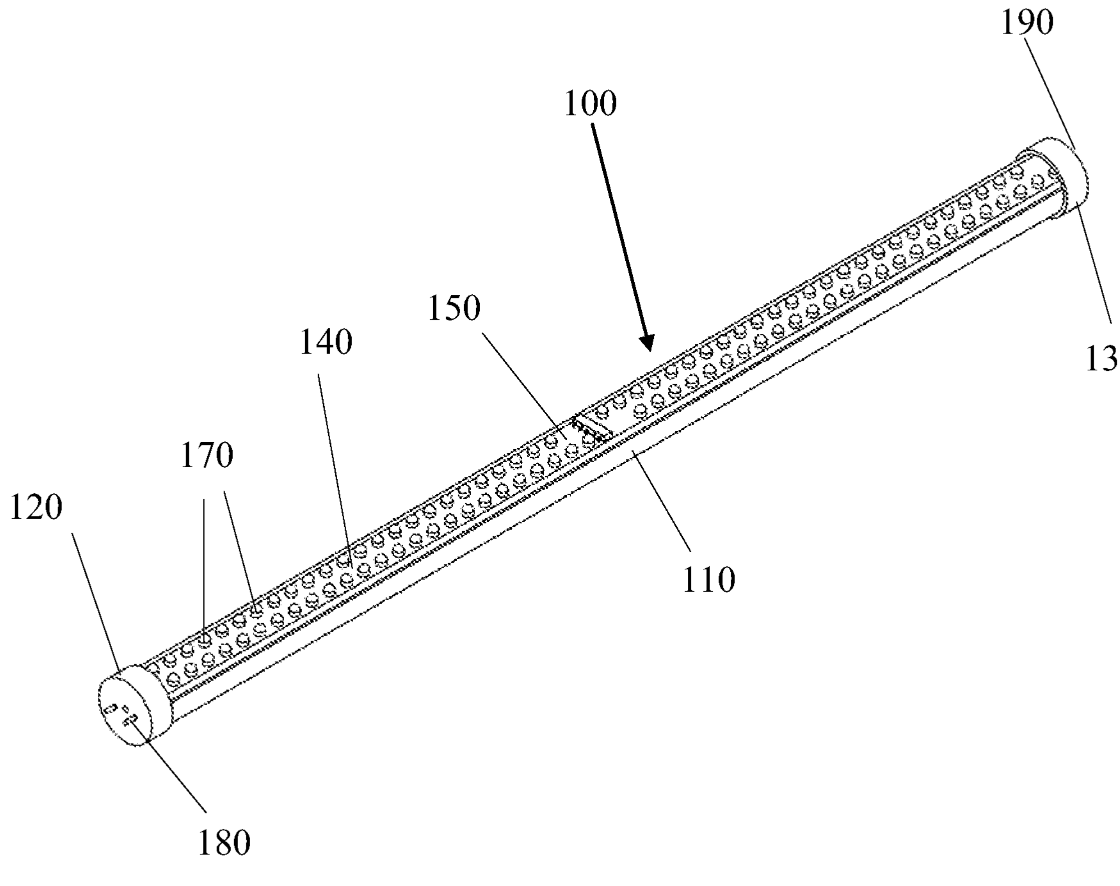


FIG. 1

PRIOR ART

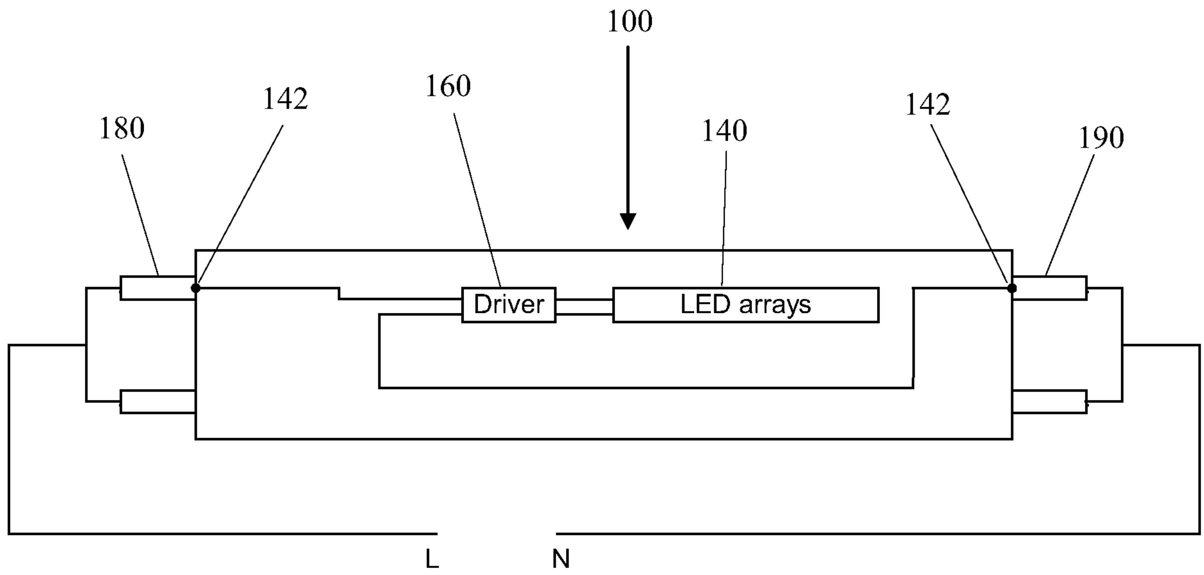


FIG. 2

PRIOR ART

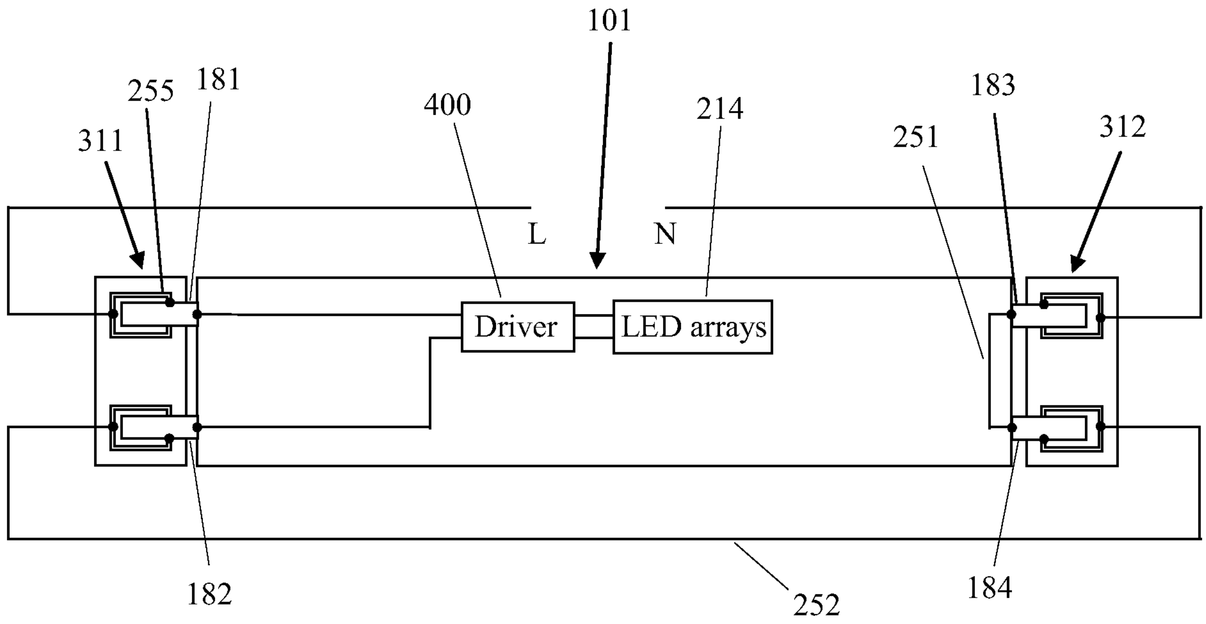


FIG. 3

PRIOR ART

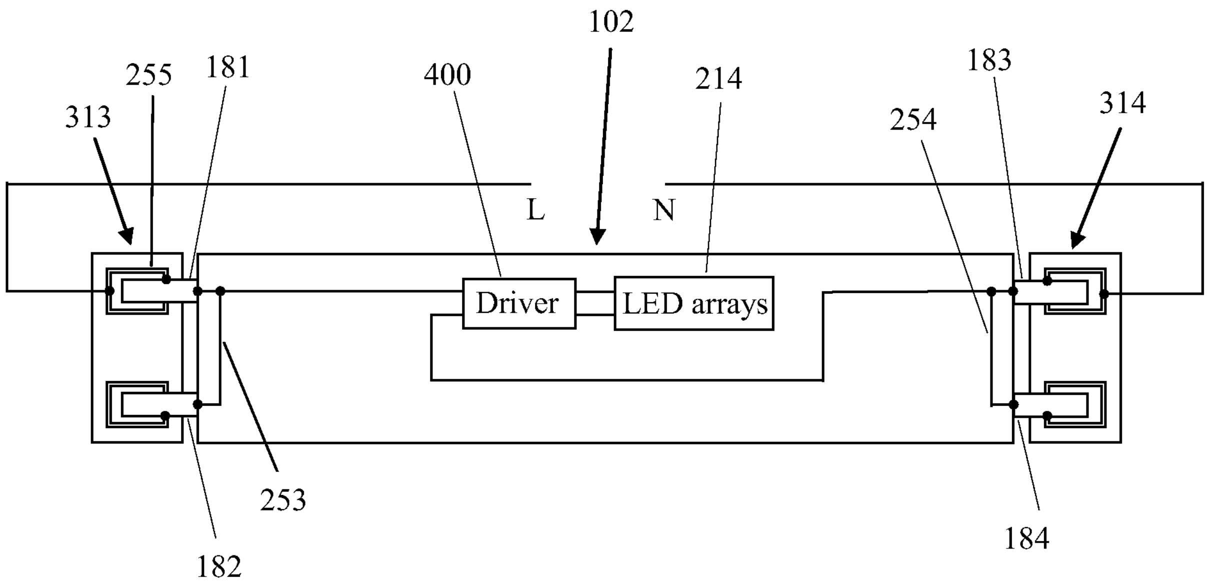


FIG. 4

PRIOR ART

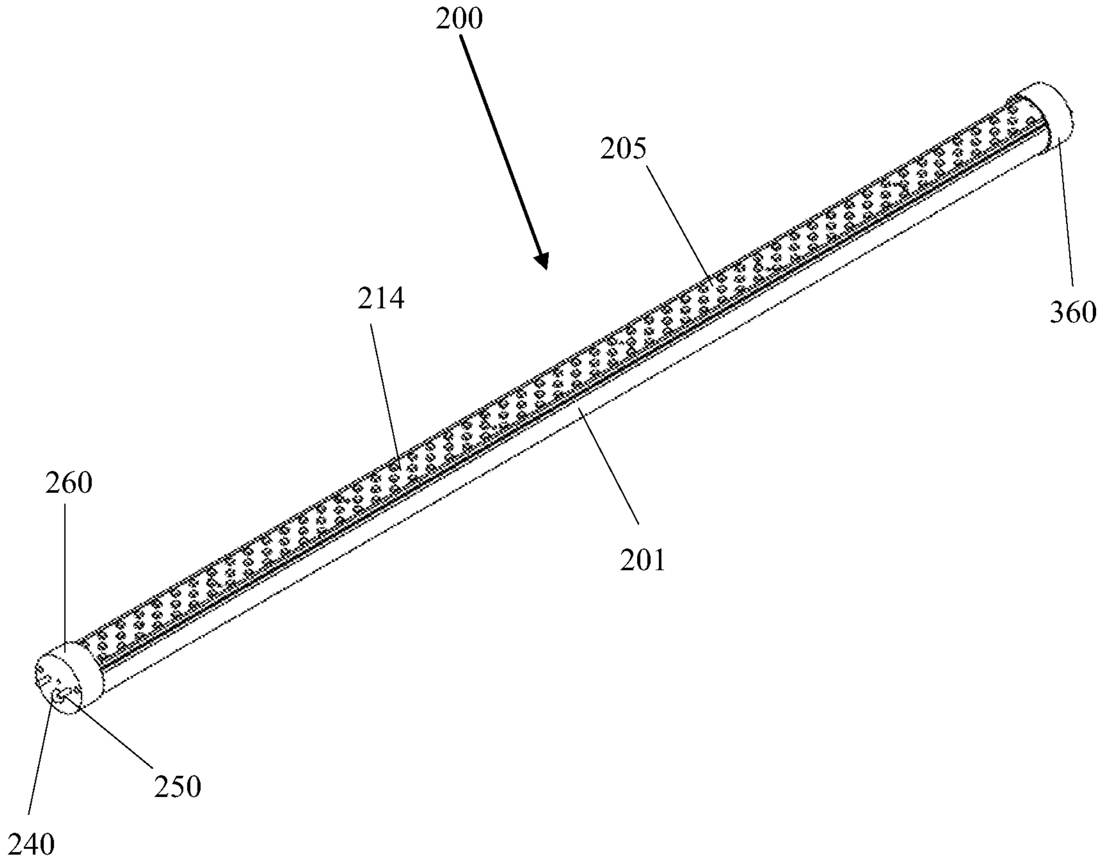


FIG. 5

PRIOR ART

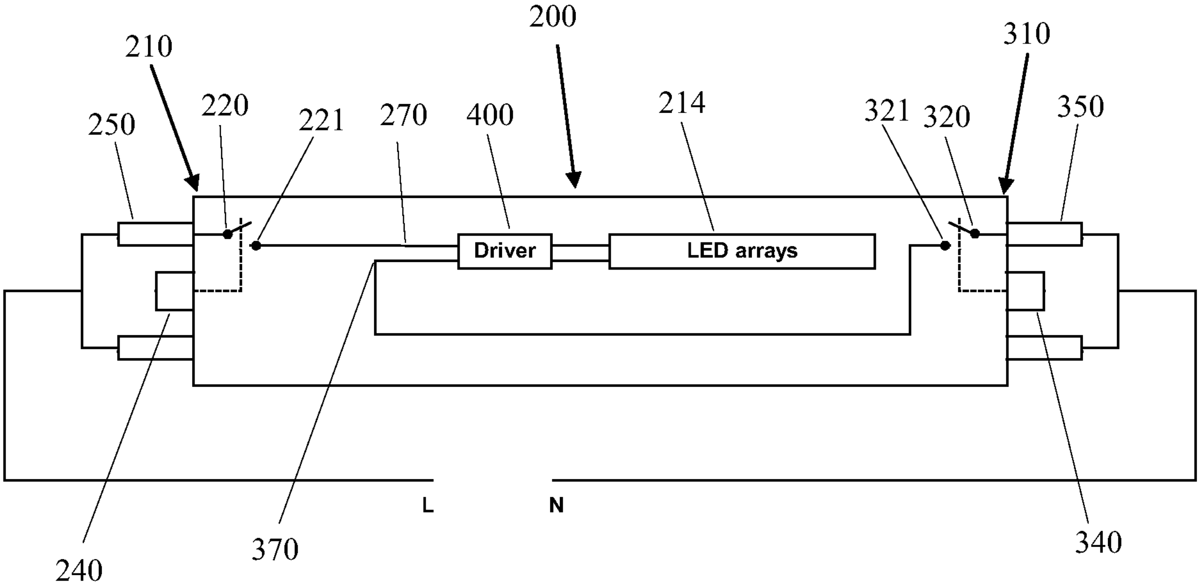


FIG. 6

PRIOR ART

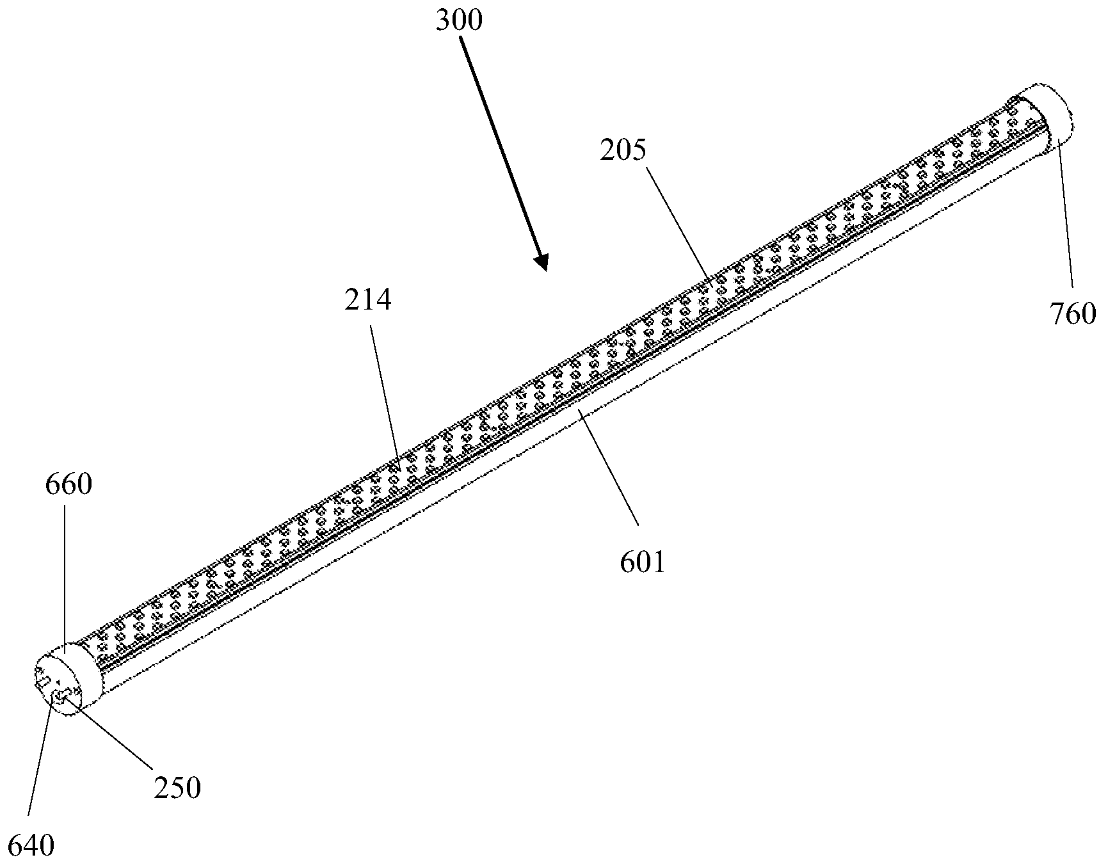


FIG. 7

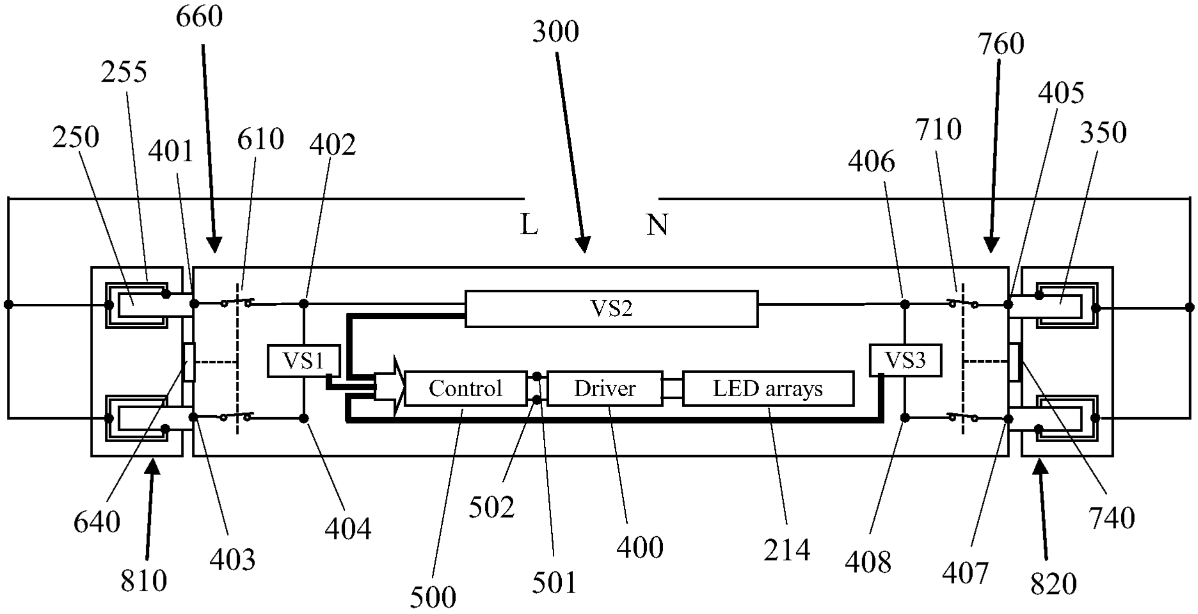
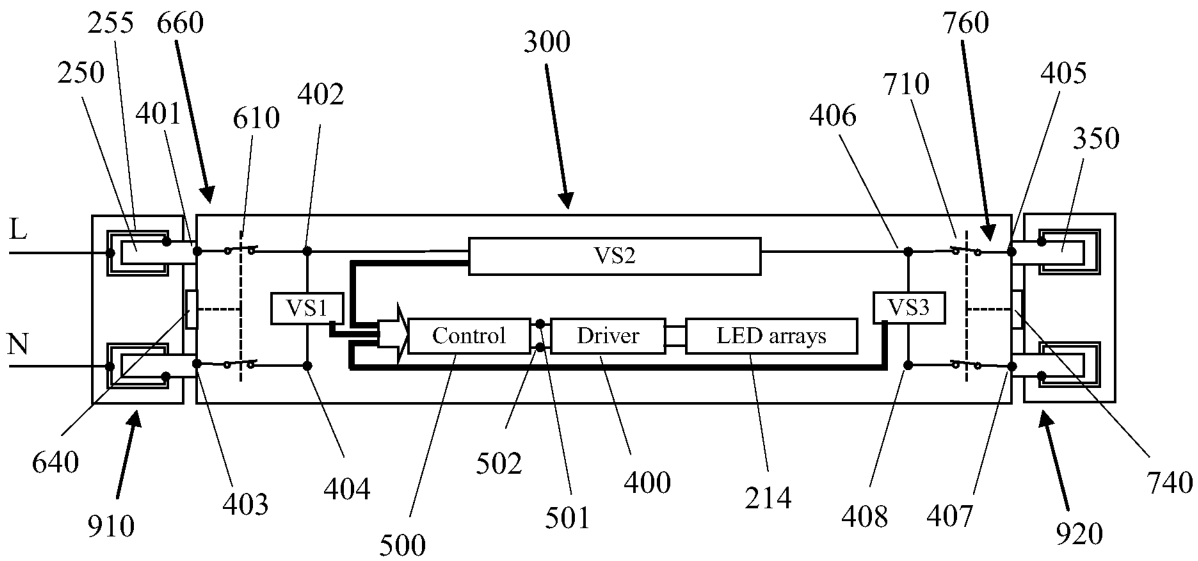

660
300
760
255
405
250
401
610
402
710
350
406
L
N
VS2
VS1
VS3
Control
Driver
LED arrays
640
404
502
400
214
408
407
740
810
403
500
501
820

FIG. 8


255
660
300
760
250
405
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610
402
710
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VS2
VS1
VS3
Control
Driver
LED arrays
640
404
502
400
214
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407
740
910
403
500
501
920

FIG. 9

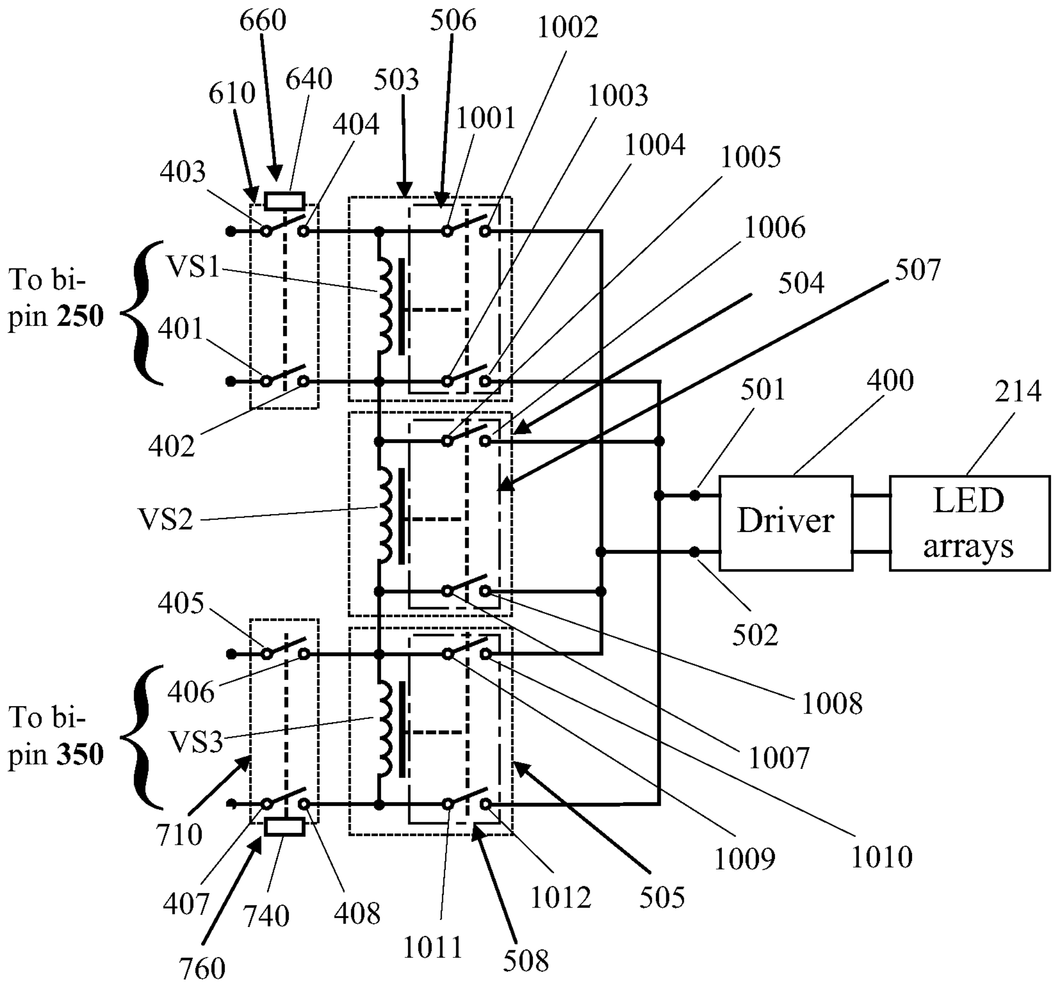
660
506
1002
640
503
610
1003
404
1001
1004
1005
403
1006
507
504
To bi-
pin 250
VS1
401
501
400
214
402
Driver
LED
arrays
VS2
502
405
1008
406
1007
To bi-
pin 350
VS3
710
1009
1010
407
740
408
1012
505
1011
508
760

FIG. 10

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2012/046918

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - F21S 4/00 (2012.01)
USPC - 362/221
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC(8) - F21S 4/00; F21V 15/04, 4/00; H05B 41/00, 37/00 (2012.01)
USPC - 362/221, 225, 394, 249.02; 315/122, 127, 128, 164

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
Patbase, Orbit.com, Proquest, GooglePatents, Micropatent

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 8,147,091 B2 (HSIA et al) 03 April 2012 (03.04.2012) entire document	1-16
A	US 2010/0156324 A1 (NAGASE et al) 24 June 2010 (24.06.2010) entire document	1-16
A	US 7,994,725 B2 (BOUCHARD) 09 August 2011 (09.08.2011) entire document	1-16
A	US 2012/0126703 A1 (JUNG et al) 24 May 2012 (24.05.2012) entire document	1-16
A	US 2012/0139421 A1 (LEE) 07 June 2012 (07.06.2012) entire document	1-16
A	US 6,525,914 B1 (LEGATTI) 25 February 2003 (25.02.2003) entire document	1-16
A	US 2012/0032610 A1 (KANG) 09 February 2012 (09.02.2012) entire document	1-16
A	US 2011/0068703 A1 (MCKINNEY) 24 March 2011 (24.03.2011) entire document	1-16
A	US 2010/0045187 A1 (SHTEYNBERG et al) 25 February 2010 (25.02.2010) entire document	1-16

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

* Special categories of cited documents:
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"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
11 September 2012	24 SEP 2012

Name and mailing address of the ISA/US	Authorized officer:
Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201	Blaine R. Copenheaver PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774