US008979299B2

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

(10) **Patent No.: US 8,979,299 B2**
(45) **Date of Patent: Mar. 17, 2015**

(54) **LINEAR SOLID-STATE LIGHTING WITH READILY RETROFITTABLE MODULAR STRUCTURE**

(71) Applicant: **Lightel Technologies, Inc.**, Renton, WA (US)

(72) Inventors: **Chungho Hsia**, Bellevue, WA (US); **Pai-Sheng Shen**, Bellevue, WA (US)

(73) Assignee: **Lightel Technologies, Inc.**, Renton, WA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 152 days.

(21) Appl. No.: **13/896,325**

(22) Filed: **May 17, 2013**

(65) **Prior Publication Data**

US 2014/0340884 A1 Nov. 20, 2014

(51) **Int. Cl.**

F21S 4/00	(2006.01)
F21V 23/02	(2006.01)
F21V 23/00	(2006.01)
F21K 99/00	(2010.01)

(52) **U.S. Cl.**

CPC ***F21V 23/009*** (2013.01); ***F21K 9/17*** (2013.01); *F21K 9/175* (2013.01); *Y02B 20/386* (2013.01); *Y10S 362/80* (2013.01)

USPC **362/221**; 362/217.13; 362/217.17; 362/225; 362/249.02; 362/800

(58) **Field of Classification Search**

CPC F21V 21/005; F21V 23/009; F21K 9/17; F21K 9/175; Y02B 20/386

USPC 362/217.01, 217.1–217.17, 221, 225, 362/249.02, 800

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2012/0306342 A1* 12/2012 Dellian et al. 313/46

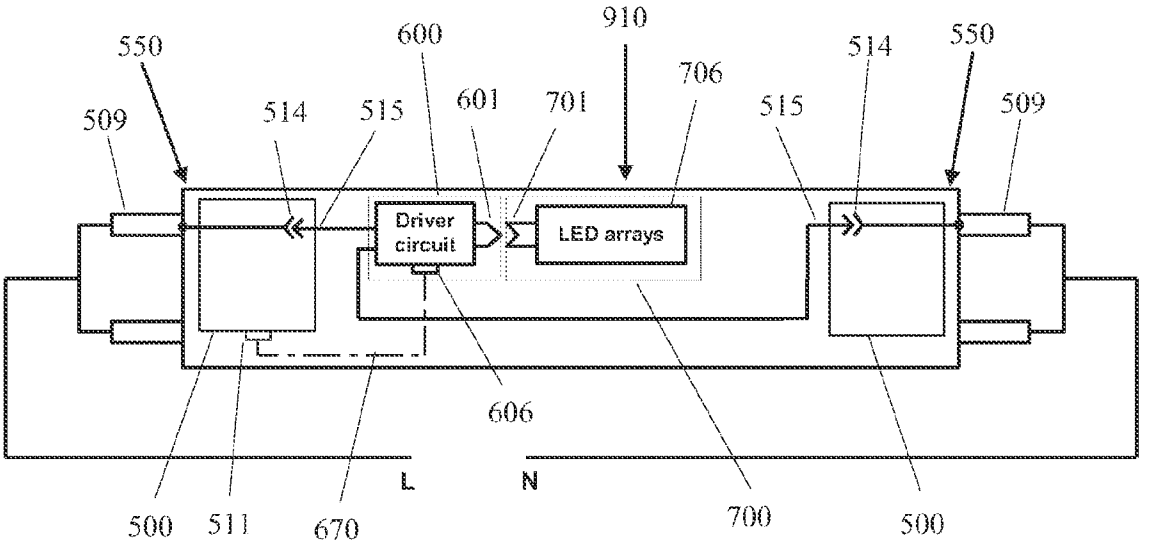
* cited by examiner

Primary Examiner — Jason Moon Han
(74) *Attorney, Agent, or Firm* — Han IP Corporation

(57) **ABSTRACT**

A linear light-emitting diode (LED) tube lamp having a readily retrofittable modular structure enables consumers or manufacturers to readily retrofit the lamp by replacing an LED module or internal electronic control units that include an LED driver in maintenance or lamp upgrade without hazards. The readily retrofittable modular structure includes a core assembly in each of lamp bases for easily securing or removing the electronic control unit through a mechanical securing means, and two sets of connection modules for quickly connecting and disconnecting the electronic control unit with the LED module. The readily retrofittable modular structure may use one bi-pin or two bi-pins to connect to the AC mains via pluggable wire for delivering power to the LEDs. Thus, the LLT lamp using the readily retrofittable modular structure may be configured as single-ended, double-ended, or double-ended with double shock-protection switches and can be cost-effectively retrofitted after initial installation.

6 Claims, 13 Drawing Sheets



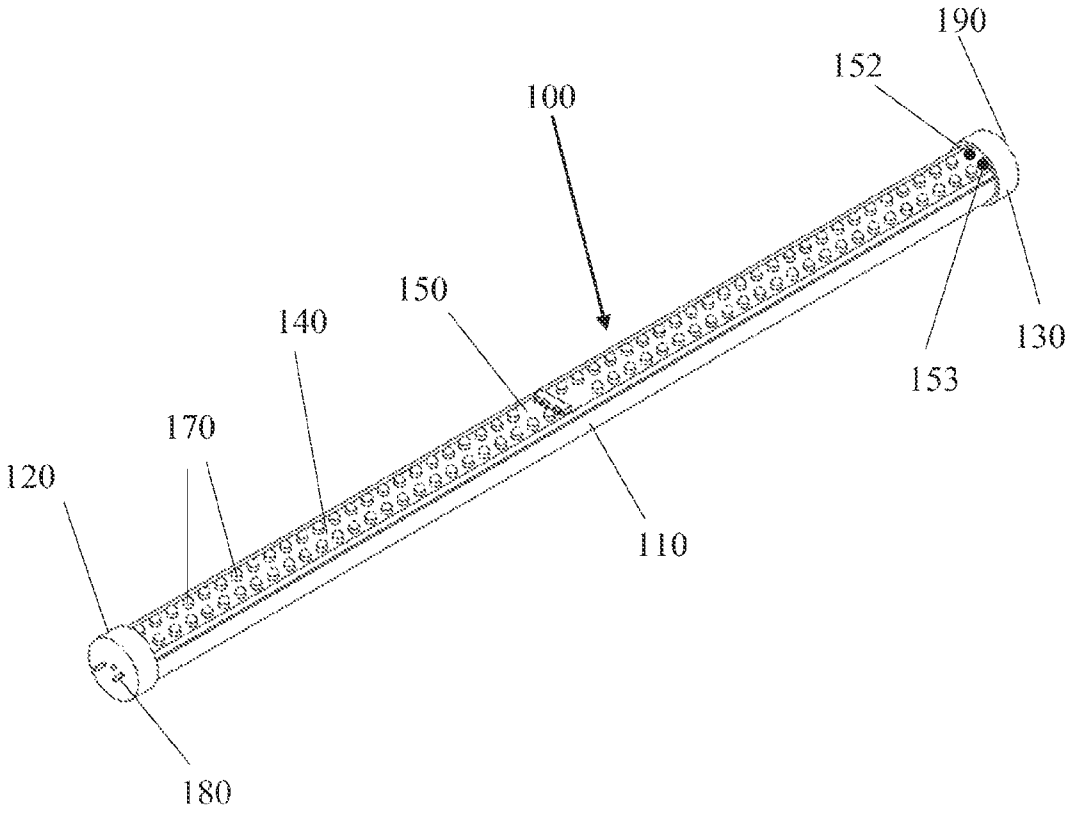


FIG. 1

PRIOR ART

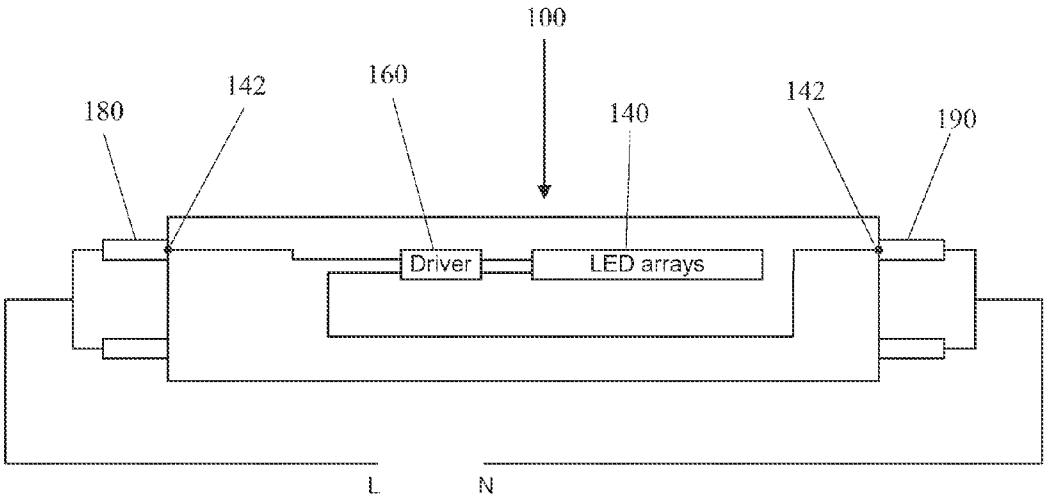


FIG. 2

PRIOR ART

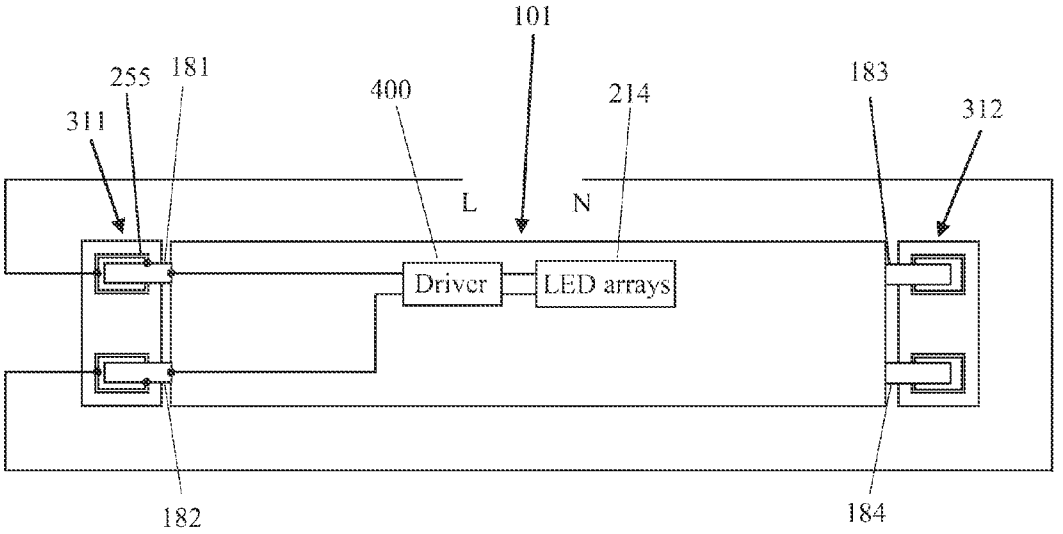


FIG. 3

PRIOR ART

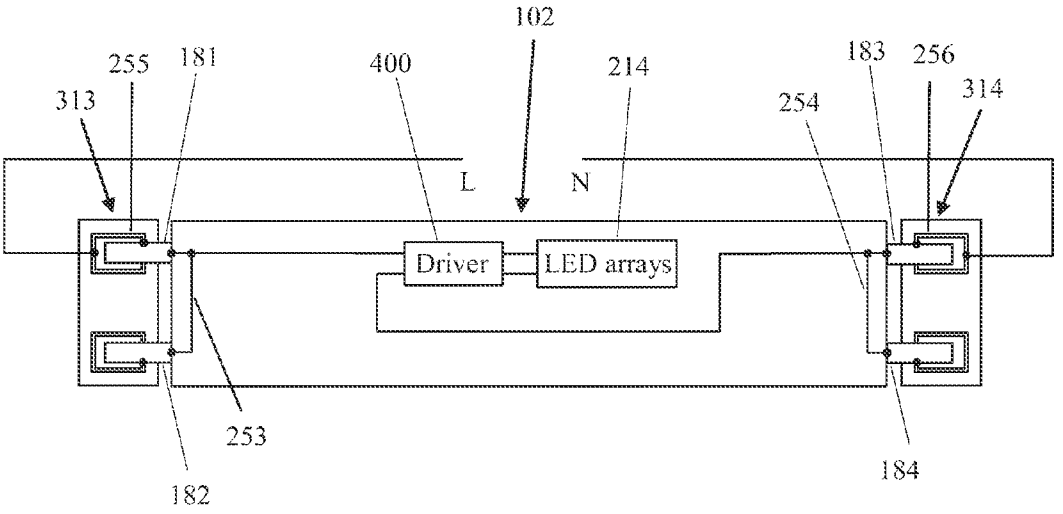


FIG. 4

PRIOR ART

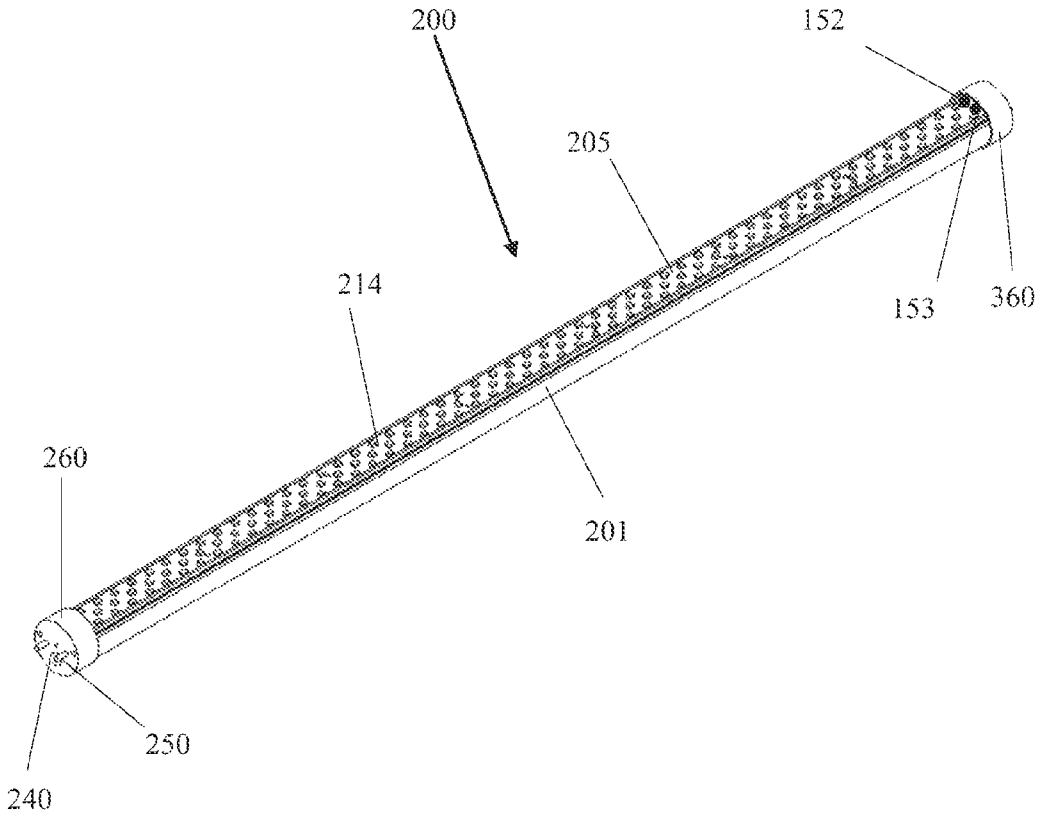


FIG. 5

PRIOR ART

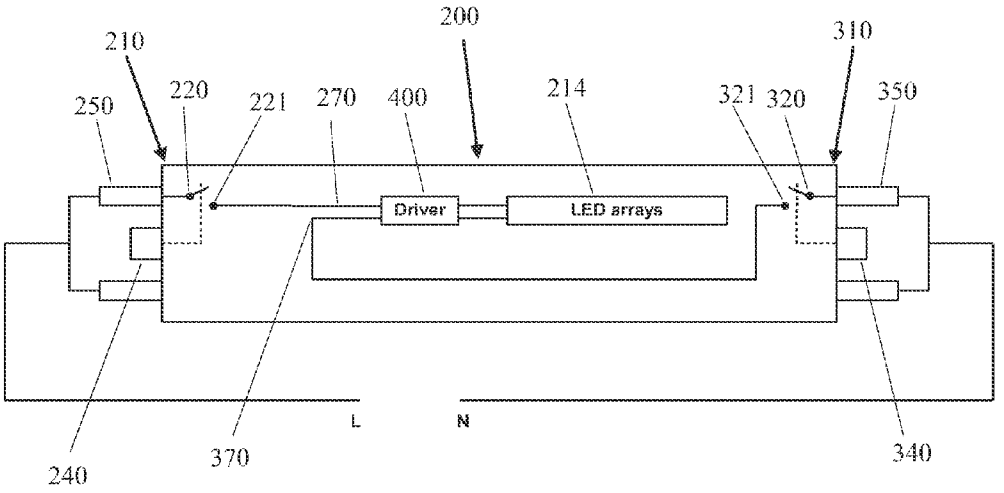


FIG. 6

PRIOR ART

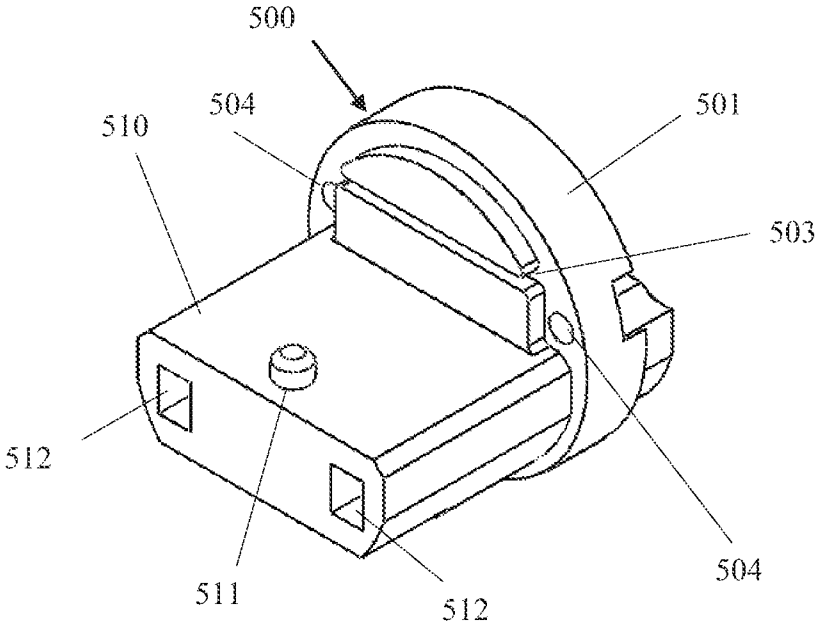

500
504
501
510
503
512
504
511
512

FIG. 7

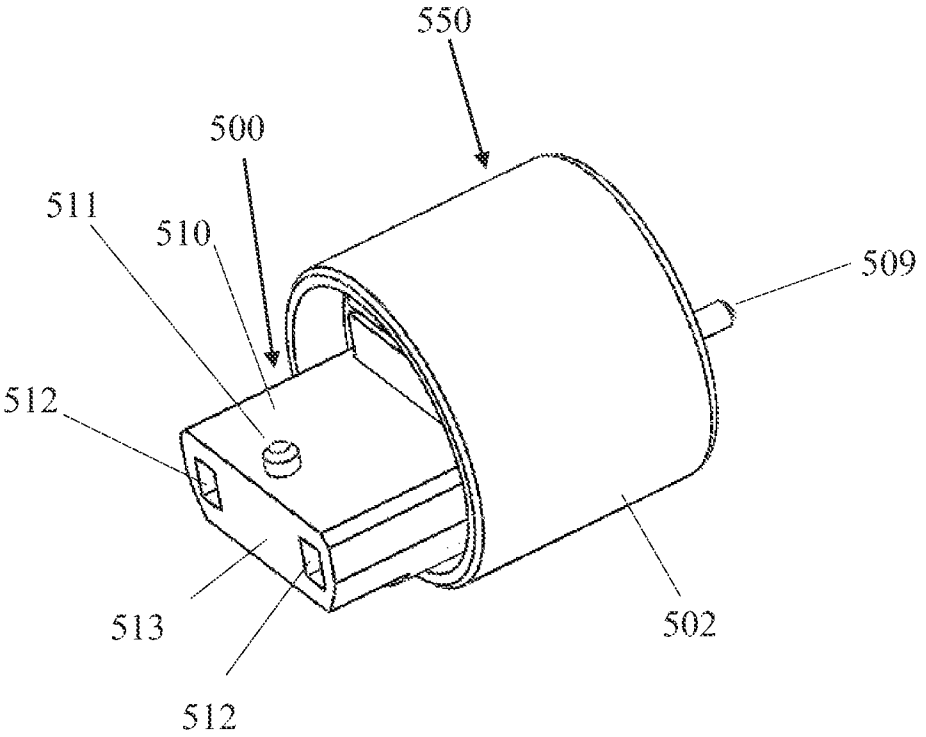

550
500
511
510
509
512
513
502
512

FIG. 8

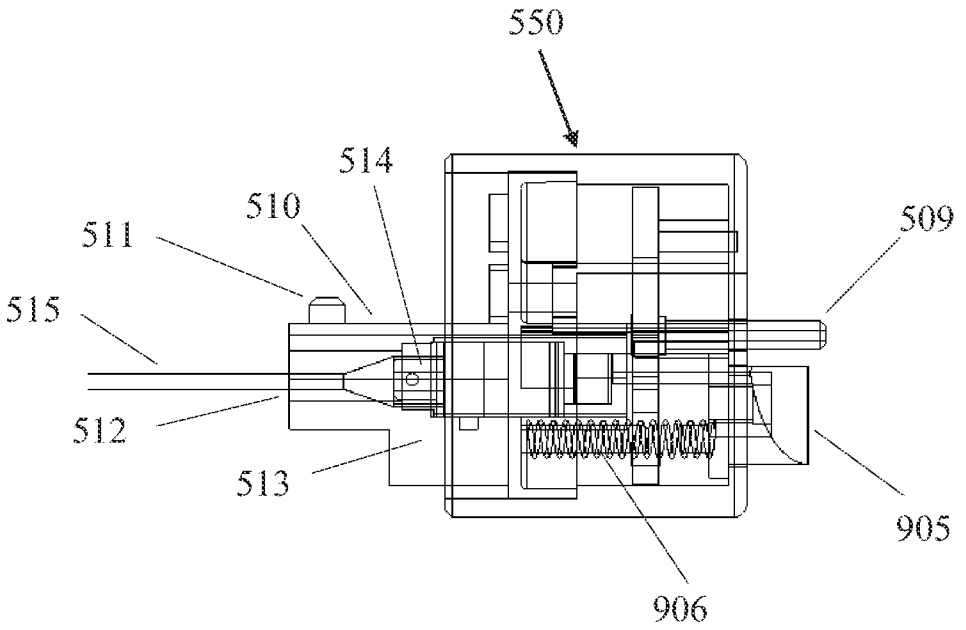

550
514
510
511
509
515
512
513
905
906

FIG. 9

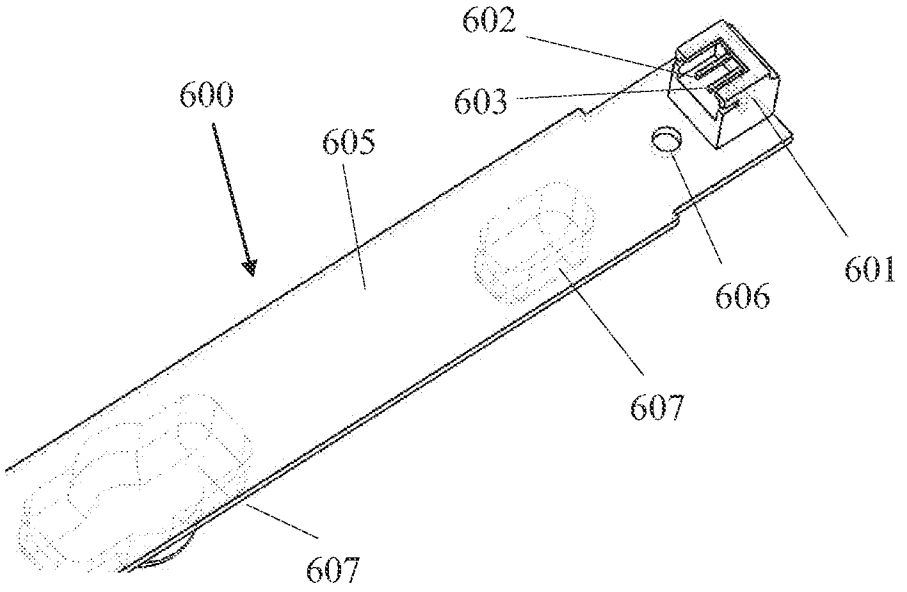

602
600
603
605
601
606
607
607

FIG. 10

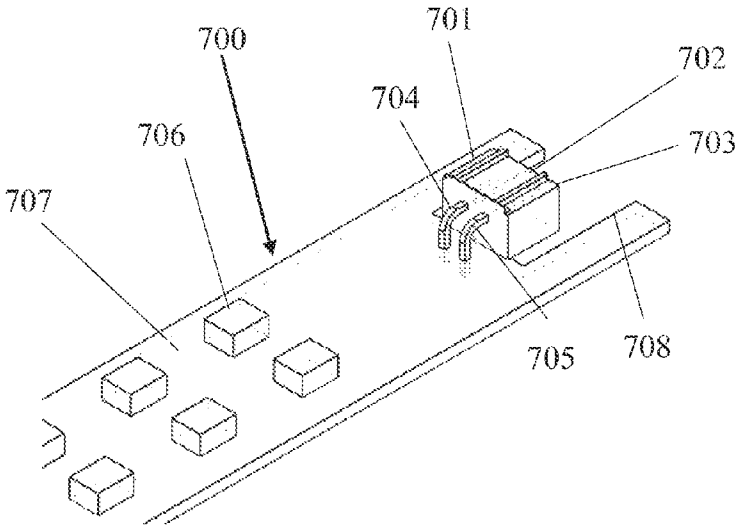

700
701
702
704
706
703
707
705
708

FIG. 11

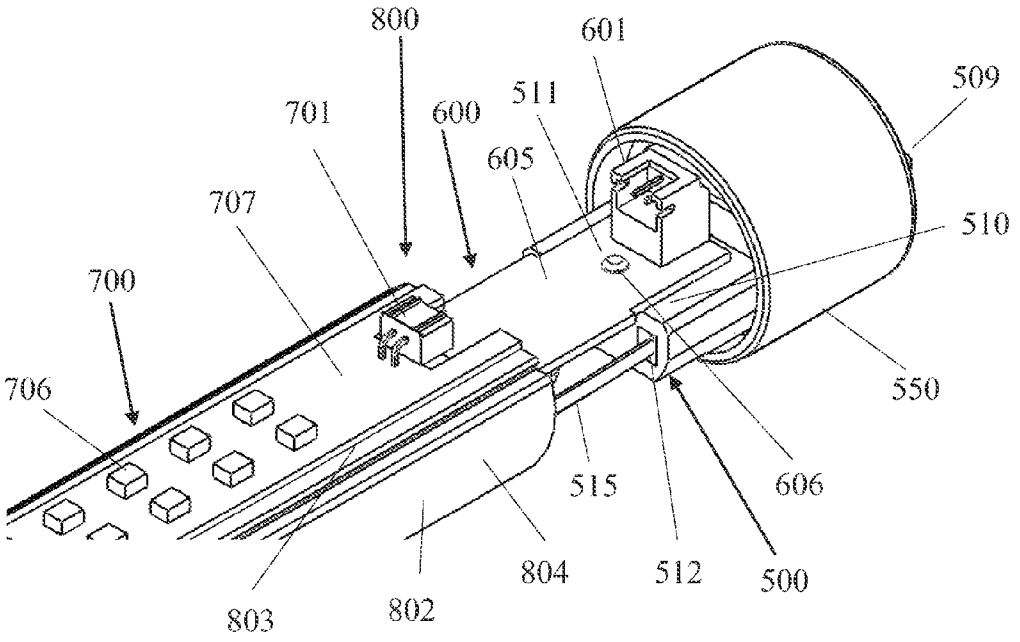

800
601
509
511
701
600
605
707
510
700
706
550
606
515
804
512
500
803
802

FIG. 12

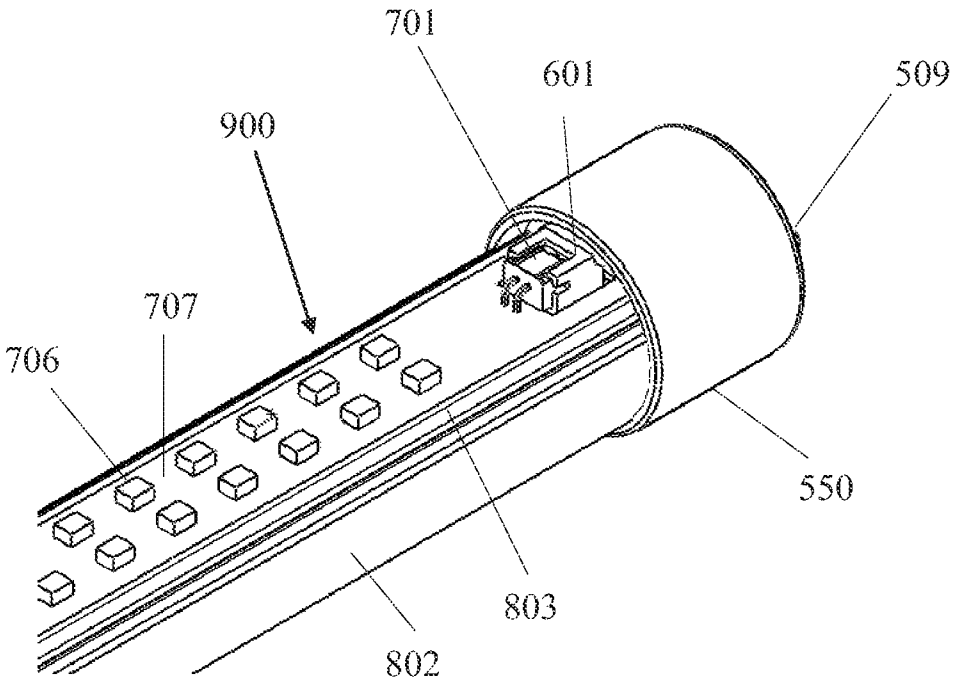


FIG. 13

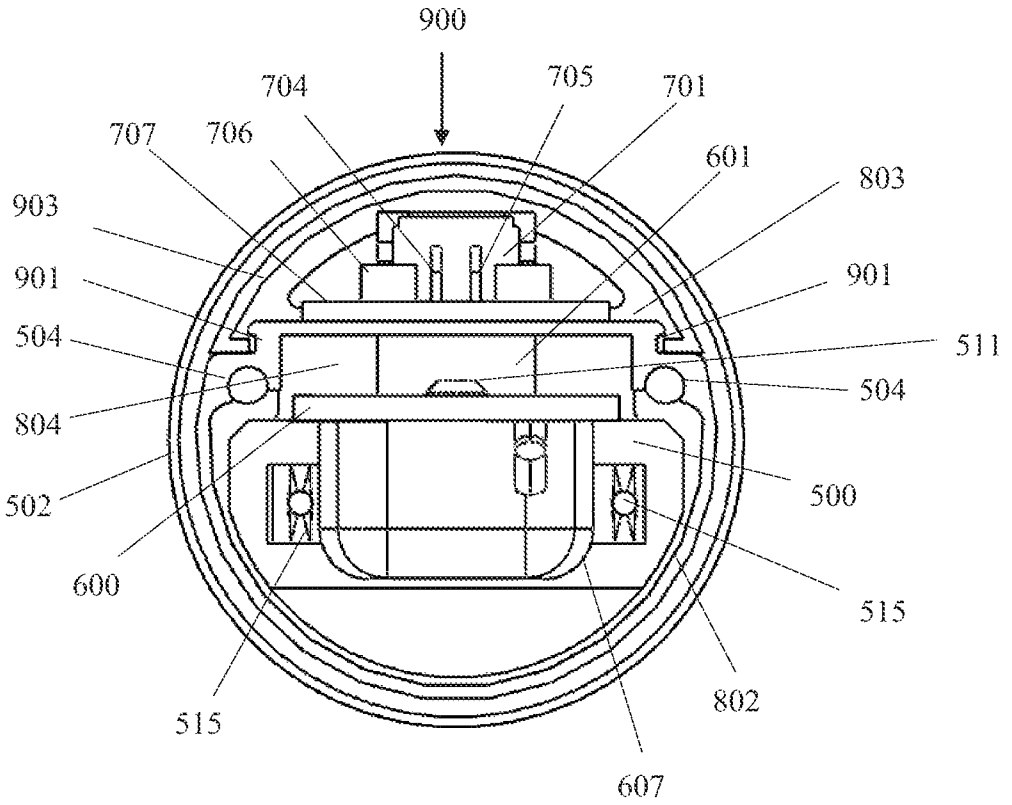

900
704
705
701
707
706
601
803
903
901
901
504
511
504
804
500
502
600
515
515
802
607

FIG. 14

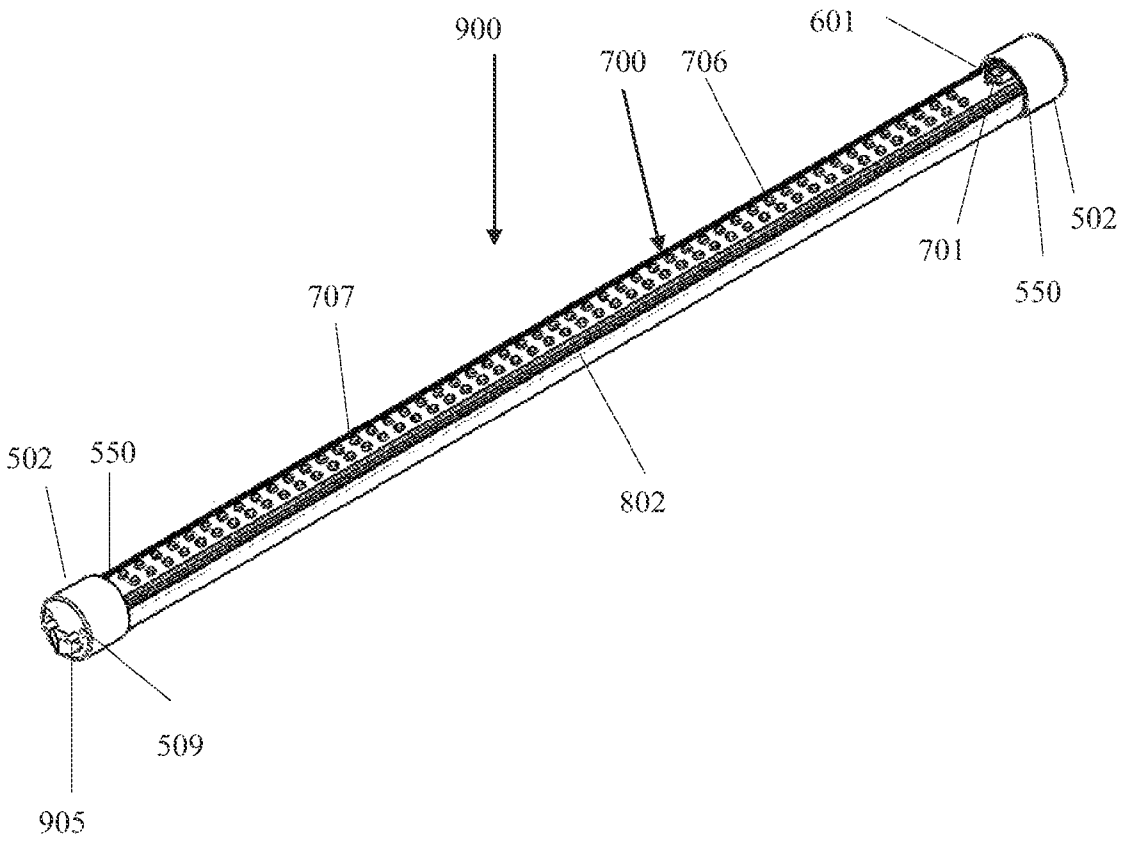


FIG. 15

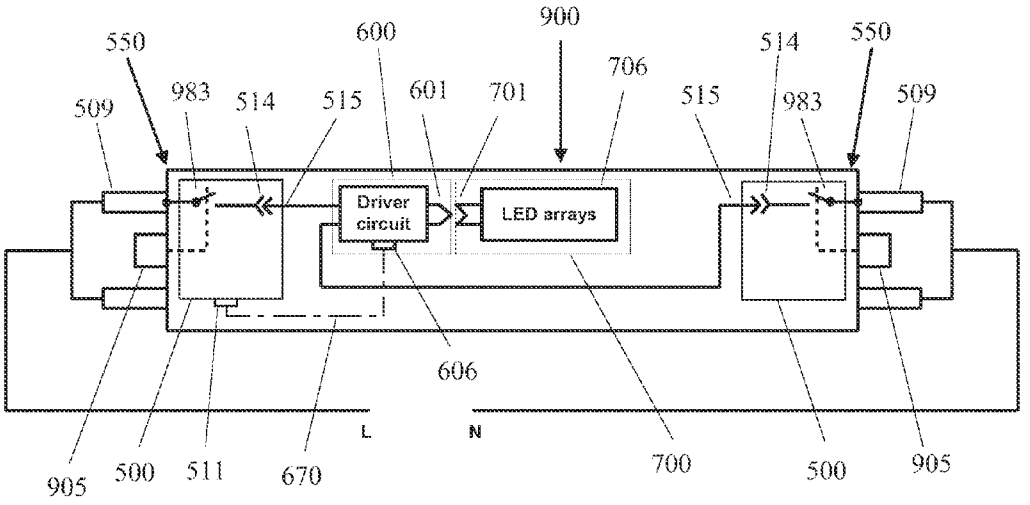

550
600
900
514
550
509
983
514
515
601
701
706
515
983
509
Driver circuit
LED arrays
606
L
N
905
500
511
670
700
500
905

FIG. 16

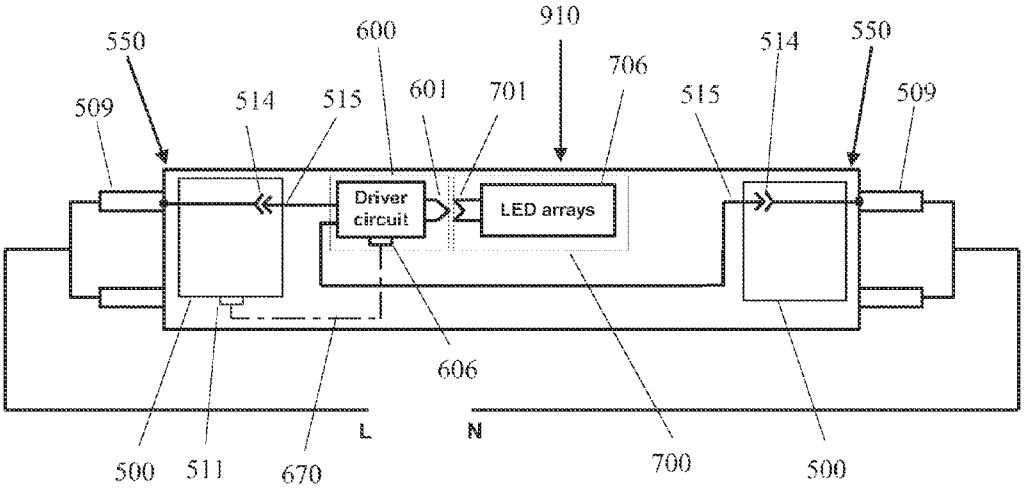

550
600
910
514
550
509
514
515
601
701
706
515
509
Driver circuit
LED arrays
606
L
N
500
511
670
700
500

FIG. 17

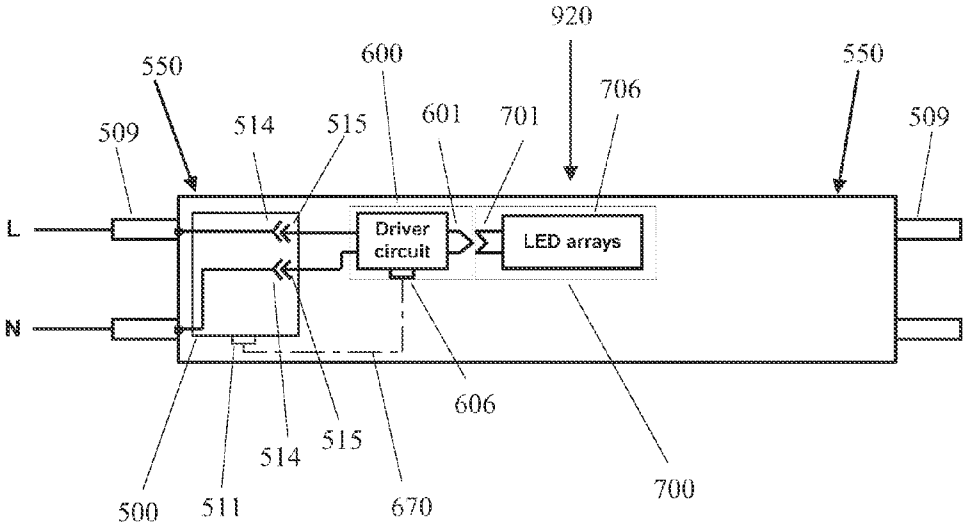

920
550
600
550
706
509
514
515
601
701
509
L
Driver circuit
LED arrays
N
606
514
515
500
511
670
700

FIG. 18

LINEAR SOLID-STATE LIGHTING WITH READILY RETROFITTABLE MODULAR STRUCTURE

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to a linear light-emitting diode (LED) lamp, and more particularly to a linear LED lamp with a readily retrofittable modular structure that enables consumers or manufacturers to readily retrofit, maintain, or upgrade the lamp by replacing an LED module or an internal LED driver. With such a retrofittable modular structure, all the workable parts with specifications that meet market demands can be reused to save resources and to reduce waste on the earth.

2. Description of the Related 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 (no hazardous materials used), higher efficiency, smaller size, and much 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 such a "green" LED lighting for their illumination applications. In this trend, even though no hazardous materials are used in an LED lamp, the lamp material reuse becomes an important environmental issue and needs to be well addressed.

Whereas environmental interest groups persist to urge businesses to pay more attention to their environmental policy, Environmental Protection Agency (EPA) continues to encourage people and businesses to conserve energy, reduce waste, and even lower carbon footprint by recycling and reusing materials. On the LED lamp market, quite a number of so called "green" consumers express preferences for products and firms that are recognized to be more environment-friendly than other competitive products and companies. Such green consumers always check potential LED lamps to see if they are either recyclable or made from interchangeable parts. Besides, some green consumers express their concerns about LED lamps' durability, not just to get one at a cheaper price because they know LED lamps that are more durable and repairable will last longer and therefore produce less garbage in the long run. "Green" investors including individuals and organizations always want to put their money where their environmental values are, especially for solid-state lighting—"green" products based on "green" technologies. In this sense, the linear LED tube lamp manufacturers should make an environmental decision to make their products to be more eco-friendly to be successful.

Although LEDs themselves can operate at least 50,000 hours, the LED driver that operates the LEDs in a linear LED tube (LLT) lamp in most cases cannot last so long because of potential failures of a LED driver in which electrolytic capacitors or other electronic components used are likely to fail prematurely. Upon failure, the LED driver needs to be replaced. But if the LED driver, typically about 10-15% of the cost of an LLT lamp, is not cost-effectively replaceable, then the whole lamp needs to be replaced and becomes waste. However, if the LLT lamp is so designed that internal LED driver can be easily removed and replaced, consumers or manufacturers can replace the LED driver only and not the whole lamp. That way, the manufacturers can reuse all other

workable parts with specifications that meet market demands and rebuild the LLT lamp, saving about 85-90% of cost of the lamp with all the workable parts including the LED module, lamp bases, heat sink and housing, lens, and so on.

Furthermore, as LED technologies and standards continue to develop rapidly, requirements of an LED luminous efficacy of 100 lumens per watt and a color rendering index (CRI) of 80 today will be unsatisfactory tomorrow to consumers and the Energy Star program. Market also requires a minimum number of surface mount LEDs used in the LED module and a specific correlated color temperature (CCT) tolerance for LED chips. So, for example, a minimum requirement of 264 LEDs in a 4-ft-T8 LLT lamp and a CCT tolerance of 175 K (Kelvin) today may be obsolete tomorrow. Similarly for LED drivers, requirements of a power factor of 0.9, a total harmonic distortion (THD) less than 20%, and a power consumption of 20 W today may not be good enough tomorrow for energy firms to offer energy rebates, a great incentive for consumers and organizations to adopt LED lamps. In this case, outdated LED modules and LED drivers may need to be replaced with upgraded ones to meet updated consumer needs and new standards.

It is, therefore, the manufacturers' environmental responsibility to design a readily retrofittable LLT lamp such that the redesign efforts are beneficial to lifetime cost of ownership and environmental protection. It seems simple and straightforward, but not single one of manufacturers adopts the idea and builds such products today, whereas an LLT lamp costs only several tens of dollars, and price competition continues to be severe on the market; manufacturers are just trying to produce such LLT lamps at the lowest cost.

To retrofit a conventional LLT lamp for replacing an existing LED driver, one must first remove the two end caps and then cut the AC wires that connect to the AC mains through two opposite bi-pins in the two end caps or de-solder the wires from their respective soldering joints in the two end caps. Then one must disconnect DC wires connected between the LED driver and the LED module by cutting or de-soldering the wires from their respective soldering joints/contacts on the LED PCB (printed circuit board). If the LED driver is not mechanically fixed, then it can be removed immediately after all the wires are released. However, the LED driver should be mechanically secured in an LLT lamp, not relying solely on the electrical contacts, to prevent possible electric shock hazards that occur when any one of the wires is accidentally detached from the soldering joint with the exposed conductor touching the metallic housing. Therefore, Underwriters Laboratories (UL) requires the LLT lamp to meet this consumer safety need. If the LED driver is fixed inside an LLT lamp using a rivet, then one needs to first remove the LED PCB on the upper platform of the lamp housing and then drill the rivet out of the place and then remove the LED driver. The replacement work is tedious and labor intensive; when LED PCB is removed from the platform of the aluminum housing, the LED PCB becomes bent, preventing it from reuse. Thus, no manufacturers would like to replace the LED driver even though the LED driver is broken, but would rather replace the whole lamp, leaving the whole non-operable lamp as a piece of garbage. This kind of products is not eco-friendly and will eventually be rejected by consumers, especially by "green" consumers.

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, 110 V, 220 V, or 277 VAC, 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. In some conventional LLT lamps, the LED driver wrapped by an insulation paper or a heat shrinking tube is inserted into the LLT lamp without being mechanically secured. The electrical wires connected to the AC mains may come off from the soldering joints at the electrical contacts **142**, which may create a safety issue not acceptable for UL and consumers. Therefore, in some conventional LLT lamps, a rivet (not shown) on the upper platform of the housing is used to secure the LED driver in place under the platform. When the LED PCB is attached on the upper platform of the housing, the rivet can no longer be accessed without first detaching LED PCB from the housing. This means that the LED driver cannot be removed unless the rivet is removed first. Soldering joints **152** and **153** are used to connect the LED driver output DC+ and DC− to the LED arrays. The bi-pins **180** and **190** on the two opposite end caps **120** and **130** connect electrically to the AC mains 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 is not yet 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 an 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 because 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.

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 bi-pin at the other end of the LLT lamp electrically insulated. Thus, 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 bi-pin at the other end only serves as a lamp holder to support the LLT lamp mechanically in the fixture. The LLT lamp configured this way is therefore called "single-ended".

In FIG. **3**, the AC mains supply voltage to the bi-pin socket **255** in the lamp holder **311** from an end of the LLT lamp **101** leaving the lamp holder **312** electrically insulated—a single ended configuration. Two pins **181** and **182** of the bi-pin are at one end, from which the driver **400** receives energy to power the LED arrays **214**. The conductors in the bi-pin socket **255** of the lamp holder **311** 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 FIG. **4**, the driver **400** receives energy from both bi-pin sockets **255** and **256** in the lamp holders **313** and **314** at opposite ends of the LLT lamp **102** to power the 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 of the two pins **181** and **182** in the bi-pin socket **255** and either one of the two pins **183** and **184** in the bi-pin socket **256** receive power, the LLT lamps can operate.

In the U.S. Pat. No. 8,147,091, issued Apr. 3, 2012, the entirety of which is incorporated herein by reference, 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 shock hazards. FIGS. **5** and **6** illustrate an LLT lamp with such shock protection switches. The LLT lamp **200** comprises 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**. Soldering joints **152** and **153** are used to connect the driver output DC+ and DC− to the LED arrays.

FIG. **6** is a block diagram of an LLT lamp **200** with the shock 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 shock 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 shock 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 shock protection switches **210**, **310** are normally off. Only after being actuated, will the shock protection switches turn "on" such that they connect the AC mains to the LED driver **400** that in turn powers the LED arrays **214**. Serving as gate controllers between the AC mains and the LED driver **400**, the shock 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 can occur 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 elimi-

nates the possibility of shock hazard for a person who installs an LLT lamp in the existing fluorescent tube fixture.

Almost all the commercially available LLT lamps today—single-ended, double-ended, or double-ended with double shock-protection switches use wire soldering approach to directly connect the LED driver output to the LED arrays and to directly connect the bi-pins in the end cap to the LED driver inputs. This approach prevents the LED driver used from being easily replaced in the first place. Furthermore, the driver not being mechanically secured may create consumer safety problems whereas the driver being mechanically secured with rivets, screws, or some other improper ways, is even more difficult to be replaced.

SUMMARY OF THE INVENTION

It is an object of the invention to provide a readily retrofittable modular structure for any LLT lamps configured as single-ended, double-ended, or double-ended with shock protection switches so that the internal driver used in such LLT lamps can be replaced as easily as an external driver, which sometimes can be replaced without disassembling the lamp itself in the field. Retrofitting an LED module that comprises LED arrays and the lamp housing is the same as replacing an LED driver. Only difference is that the driver removed is to be reused with an upgraded LED module. This is essential for long-term maintenance and retrofit for linear LED lighting products.

According to the invention, the retrofittable LLT lamp comprises an elongated housing having two ends and a platform on a top side thereof between the two ends; an LED PCB fixed on top of the platform, the LED PCB having LED arrays and at least one first connection module thereon; at least one electronic control unit that controls the power to the LED arrays on the LED PCB, the at least one electronic control unit having two inputs and a second connection module thereon; and two lamp bases respectively connected to the two ends of the housing, each lamp base having an end cover comprising a bi-pin with two pins protruding outwards through the end cover and an intermediate core assembly comprising a securing means used to mechanically couple one electronic control unit and a compartment used to accommodate at least one connection terminal for one AC power pluggable wire.

In an embodiment, at least one electronic control unit is an LED driver. The LED driver is mechanically coupled with a first core assembly through the securing means that comprises a dowel to couple a hole on the LED driver and a platform on the core assembly to partially support the LED driver in a way that when the lamp base is coupled with the lamp housing, the LED driver is pushed into a hollow compartment under the platform of the lamp housing, and the second connection module on the LED driver is automatically coupled with the first connection module on the LED PCB to make a reliable DC power connection. In the single-ended lamp, the AC power connection is done by using two AC pluggable wires plugging onto the connection terminals in the first core assembly in the lamp base. In the double-ended lamp, the AC power connection is done by using two AC pluggable wires plugging onto the connection terminals, each in the first core assembly and a second core assembly in the lamp bases. For the double-ended lamp with double shock protection switches, the AC power connection is done by using two AC pluggable wires plugging onto the connection terminals on the switches, each in the first core assembly and a second core assembly in the lamp bases.

With this readily retrofittable modular structure (readily retrofittable mechanism, thereafter), the linear LED lamp can be cost-effectively retrofitted or upgraded. For example, when the LED driver needs to be replaced, one can remove the lamp base to pull out the LED driver, and at the same time to electrically and mechanically disconnect the LED driver from the LED PCB. Then one can unplug the two AC pluggable wires from the connection terminals in the core assembly/assemblies, depending on single- or double-ended configuration. This way, the LED driver can be taken out from the lamp without cutting or de-soldering any wires. Similarly for installing a new LED driver, one can just follow reverse procedures, no need to make wire connections or to solder any wires. What is most important is that because the AC connection terminals are embedded inside the core assembly/assemblies which are made of an insulated plastic material, and because DC connection between the LED driver and the LED PCB is through the connection modules thereon, AC and DC paths are well separated and insulated; there is no possibility that the AC voltage can mess up in the DC path with a leakage current flowing on the metallic housing, which may create an electric shock hazard for consumers. To prevent consumers from injury due to this shock hazard, UL uses one of the procedures in UL 1993 Standards, Dielectric Voltage-Withstand Test, to determine if LLT lamps under test meet the consumer safety requirements.

Because the readily retrofittable mechanism implemented in the LLT lamp enables consumers or manufacturers to cost-effectively upgrade the LLT lamp without possible misuse of mechanical and electrical connections between the LED PCB and the LED driver and between the LED driver and the AC connection terminals, they are willing to do the upgrade by only replacing the LED driver or the LED module that need to be replaced. Therefore, all the workable parts such as the LED driver, the LED module comprising a plurality of LEDs on the LED PCB, the heat sink or lamp housing, lamp bases, and the lens to be described in detail below can be reused to save resources and to reduce waste on the earth.

BRIEF DESCRIPTION OF THE 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 a block diagram of a conventional single-ended LLT lamp.

FIG. **4** is a block diagram of a conventional double-ended LLT lamp.

FIG. **5** is an illustration of a double-ended LLT lamp with shock protection switches.

FIG. **6** is a block diagram of a double-ended LLT lamp with shock protection switches.

FIG. **7** is a perspective view of a core assembly in a lamp base according to the present invention.

FIG. **8** is a perspective view of a lamp base comprising the core assembly according to the present invention.

FIG. **9** is a side view of a lamp base comprising the core assembly and a pluggable wire according to the present invention.

FIG. **10** is a perspective view of a connection module in an LED driver according to the present invention.

FIG. **11** is a perspective view of a connection module in an LED lighting board according to the present invention.

FIG. **12** is a perspective view of an embodiment of the readily retrofittable mechanism before the lamp base is coupled to an LLT lamp according to the present invention.

FIG. **13** is a perspective view of an embodiment of the readily retrofittable mechanism after the lamp base is coupled to an LLT lamp according to the present invention.

FIG. **14** is a cross-sectional view of an embodiment of the readily retrofittable mechanism in an LLT lamp according to the present invention.

FIG. **15** is a perspective view of a double-ended LLT lamp with shock protection switches and with the readily retrofittable mechanism according to the present invention.

FIG. **16** is a block diagram of a double-ended LLT lamp with shock protection switches and with the readily retrofittable mechanism according to the present invention.

FIG. **17** is a block diagram of a double-ended LLT lamp with the readily retrofittable mechanism according to the present invention.

FIG. **18** is a block diagram of a single-ended LLT lamp with the readily retrofittable mechanism according to the present invention.

DETAILED DESCRIPTION OF THE INVENTION

Referring to FIGS. **7**, **8**, **9**, and **14**, a core assembly **500** comprises a circular interface ring **501** concentric to the inner wall of an end cover **502**, a horizontal channel **503** used to position the core assembly **500** with the aluminum heat sink housing **802** (in FIG. **14**) by embedding an end of platform **803** (in FIG. **14**) of the heat sink housing **802** into the channel **503**, a supporting surface **510** to support an LED driver **600** (in FIG. **14**), a mechanical securing means **511** on the supporting surface **510** to hold and secure the LED driver **600**, a bi-pin **509** for connecting to a socket for an LLT lamp, a hollow compartment **513** under the supporting surface **510** for holding the AC connection terminals **514** (in FIG. **9**) and a lead wire (not shown) that electrically connects to a bi-pin **509**, and two holes **512** each for accommodating an AC power pluggable wire **515** inserted and connected to one of the AC connection terminals **514**. The supporting surface **510** on the core assembly **500** should be long enough to partially support the LED driver and be protruded in a way that it can be partially inside the lamp housing under the platform **803** when the lamp base **550** that includes the end cover **502** is connected to the lamp housing **802**. On the supporting surface **510**, the mechanical securing means **511** used is a dowel, which can be replaced with two or more dowels. Other possibilities for holding and securing the LED driver **600** include a tap hole with a fixing screw, a retaining clip, or other similar means. In this embodiment, the LED driver **600** is held and secured by using the mechanical securing means **511** in one of two lamp bases. Other electronic control units including a dimming control unit or a ZigBee controller may be attached to the other lamp base by the same mechanical securing means **511**.

Introducing an intermediate core assembly **500** to interface the end cover **502** and the lamp housing **802** offers another advantage which a person having ordinary skill in the art always ignore. The end cover **502** contains an outward bi-pin that connects to the AC mains, and the inner side of the end cover **502** unavoidably has exposed live traces or connection joints. Without the plastic core assembly which is insulated as an interface, when the end cover **502** and the heat sink housing **802** are connected, the live traces or the connection joints may contact the metallic heat sink and short—an electric shock hazard. So the intermediate core assembly **500** also serves as a buffer intended to physically limit access to live parts that pose a risk of electric shock. Thus, with the intermediate core assembly **500** in place, retrofitting an LLT lamp can be straightforwardly done by a consumer without any safety concern.

In FIG. **8**, the core assembly **500** is coupled with the end cover **502** to form a lamp base **550** by the concentric interface ring **501** (in FIG. **7**) and an internal positioning means in the end cover **502**. In FIG. **9**, the AC power pluggable wire **515** is further inserted into one of the holes **512** and connected to one of the AC connection terminals **514** in the hollow compartment **513**. The other end of the AC power pluggable wire **515** is connected to one of the inputs of the LED driver **600**. After installing the AC power pluggable wire **515** and an LED driver, one can install the lamp base **550** by using screws to secure the end cover **502** and the core assembly **500** through the screw holes (not shown) in the end cover **502** and the screw holes **504** (in FIG. **7**) in the core assembly **500** all the way to the end of an LLT lamp **900** (in FIG. **14**).

For the single-ended application, two holes **512** and two connection terminals **514** are needed for two AC power pluggable wires **515** to connect to the AC mains because the power is delivered from the bi-pin at the same lamp end. For the double-ended application, one of the holes **512** and one of the connection terminals **514** in each lamp base at opposite end are used to connect to the AC mains because the power is delivered from the bi-pins at the two opposite lamp ends. For the double-ended application with double shock-protection switches, the connections are the same as the double-ended application. Only difference is that the AC power pluggable wire **515** is connected to the connection terminals **514** on a shock protection switch (in FIG. **9**) in the core assembly **500**. The shock protection switch of each of the lamp bases comprises at least two electrical contacts, one electrically connected to the bi-pin of the lamp base and the other electrically connected to one of the inputs of the LED driver, now through the connection terminals **514**; and at least one switch actuation mechanism **905** (shown in FIG. **9**) having a front portion protruding outwards through the end cover of the lamp base, wherein when the front portion of the switch actuation mechanism is actuated by inserting the bi-pin of the lamp base into a lamp socket, the two electrical contacts are electrically connected to actuate the shock protection switch so that the bi-pin is electrically connected with one of the inputs of the LED driver. Spring **906** in FIG. **9** is used to provide a stretching force for the switch actuation mechanism **905** to keep deactivated so that the shock protection switch is maintained an off-state when the lamp is not in the fixture and during relamping.

In the above embodiment, only one electronic control unit which is the LED driver is used. Two electronic control units may be used with the two core assemblies at the opposite ends of the lamp, taking the same advantage of being readily retrofitted. The electronic control units that may be used in this case include the LED driver, a dimming control unit, a ZigBee controller, or an LED driver in part. The LED driver in part means that the LED driver may be divided into two parts installed respectively in the two core assemblies at the opposite ends of the lamp for another purposes.

Referring to FIGS. **10**, **11**, **12**, and **13**, the second connection module **601** in an LED driver **600** is used to electrically connect to an LED lighting board **700** through the first connection module **701** on the LED PCB **707**. Two connection pins **602** and **603** in the second connection module **601** are used to couple with two connection slots **702** and **703** (not shown) on the back of the first connection module **701** on the LED lighting board **700**. In FIG. **10**, a hole **606** on the LED driver PCB **605** is used to couple with the dowel **511** on the core assembly **500** in the lamp base **550** and to mechanically secure the LED driver **600** with the support of the supporting surface **510** on the core assembly **500** in the lamp base **550** so that when the lamp base **550** is mechanically connected with the lamp housing **802**, the LED driver **600** is pushed into the bottom compartment **804** of the lamp housing **802**, whereas

when the lamp base **550** is removed from the lamp housing **802**, the LED driver **600** is pulled out from the bottom compartment **804** of the lamp housing **802** and can then be easily removed from the dowel **511** on the core assembly **500** in the lamp base **550**. The hole **606** on the LED driver PCB **605** can also be used with the tap hole (the position of the dowel **511**) on the core assembly **500** in the lamp base **550** to mechanically secure the LED driver **600** with a fixing screw. Another possibility is that the hole **606** on the LED driver PCB **605** is used with the retaining clip on the core assembly **500** in the lamp base **550** to grip the LED driver **600** in place.

In FIG. **11**, a cutout **708** on the LED PCB **707** is used to guide and accommodate the width of the second connection module **601** on the LED driver **600**. The first connection module **701** is mounted along an edge of the cutout **708** with the pins **704** and **705** soldered on the LED PCB **707**. In FIG. **12**, the LED lighting board **700** is fixed on top of the platform **803** of the housing **802** whereas the LED driver **600** is inserted into the hollow bottom compartment **804** under the platform **803**. The platform **803** has a similar cutout as the cutout **708** to accommodate the width of the second connection module **601**. The LED PCB **707** and the driver PCB **605** are not in the same plane. So one of the challenges is how to precisely couple the two connection modules **601** and **701** such that the two connection pins **602** and **603** in the second connection module **601** can be three-dimensionally coupled with two connection slots **702** and **703** on the back of the first connection module **701** in the LED lighting board **700**. The cutout **708** provides a horizontal guiding in the first place followed by the use of the pins **704** and **705** soldered on the LED PCB **707** to provide a vertical flexibility. In combination, they can offer enough tolerance of mechanical precision and make mechanical coupling and electrical connections easier and faster, thus reducing retrofit cost. That is, when the second connection module **601** on the LED driver **600** is pushed into the first connection module **701** on the LED lighting board **700**, the two connection pins **602** and **603** in the second connection module **601** and the connection slots **702** and **703** on the back of the first connection module **701** are mated so that mechanical coupling and electrical connections can be made in the shortest period of time. This is essential for cost-effective LED driver replacement. After assembling, the two connection modules **601** and **701** are coupled with electrical connections automatically made—no lead wires or wire soldering needed. This completely eliminates electrical wire management in the small lamp base area. Furthermore, the LED lighting board **700** and the LED driver **600** are respectively disposed on top and bottom of the platform **803** of the housing **802**, separated by the platform **803**. If there is a wire interconnection between the LED lighting board **700** and the LED driver **600**, the wires must cross the platform **803** to make an electrical connection. It is possible that part of the wires is squeezed between the lamp base **550** and the cross section of the platform **803** when the lamp base **550** is fixed on the lamp housing, leading to broken wires. On the other hand, when the lamp base **550** is removed from the lamp housing **802**, the LED driver **600** is pulled out from the bottom compartment **804** of the lamp housing **802**, and at the same time, the second connection module **601** in the LED driver **600** is decoupled from the first connection module **701** in the LED lighting board **700**, automatically disconnecting the electrical connection between the LED driver **600** and the LED lighting board **700**—no wire cutting or de-soldering is needed.

In FIG. **12**, when assembling an LLT lamp **800**, the AC power pluggable wire **515** must be first inserted into the hole **512** and then plugged onto the connection terminal **514** in the core assembly **500** in the lamp base **550**. The other end of the AC power pluggable wire **515** can be soldered to the LED driver **600** or be connected with a connector on the LED driver **600** to make an AC connection. In disassembling the LLT lamp **800**, when the lamp base **550** is removed from the lamp housing **802**, the AC power pluggable wire **515** can be accessed and removed from the connection terminal **514** in the core assembly **500** in the lamp base **550**, and then the LED driver **600** can be immediately removed and replaced.

FIG. **13** is a perspective view of an embodiment of a readily retrofittable mechanism after the lamp base **550** is coupled to an LLT lamp **900** with a lens (not shown for clarity). FIG. **14** is a cross-sectional view of the LLT lamp **900** that adopts the readily retrofittable mechanism. As shown in FIGS. **13** and **14**, the elongated lamp housing **802** made of aluminum is served as a heat sink of the lamp. On the platform **803** of the lamp housing **802** is an LED PCB **707** whereon the LED arrays **706** are mounted. In the hollow bottom compartment **804** under the platform **803**, the LED driver **600** is secured on the dowel **511** (with the dowel **511** inserted through the hole **606**) on the core assembly **500** in the lamp base **550** when the lamp base **550** is coupled to an end of the lamp housing **802**. The LED driver **600** is mounted in such a way that the electronic components **607** thereof on the LED driver PCB **605** face downward. Depending on the lamp configurations—single-ended, double-ended, or double-ended with double shock-protection switches, the AC power pluggable wires **515** connect differently to the connection terminals **514** in the core assembly **500** in the lamp base **550**. For example, in the single-ended application, two AC power pluggable wires **515** are used at a single lamp base, leaving the other lamp base electrically insulated. In the double-ended application, the two AC power pluggable wires **515** are used separately in two lamp bases at two opposite ends of the lamp. For the double-ended application with double shock-protection switches, the connections are the same as those in the double-ended application except that the AC power pluggable wires **515** are connected to the connection terminals **514** on the shock protection switches in the lamp bases at the two opposite ends of the lamp. On each of the two end covers **502** are two screw holes for the two lamp bases **550** to be fixed on the lamp housing **802** to form a complete lamp. On the lamp housing **802** along two longitudinal sides of the platform **803** are two elongated troughs **901** to secure the lens **903**, through which the LED arrays emit the light to the ambient. The installation and removal of the lens **903** should be easy because of this trough design. On the LED PCB **707**, the connection module **701** is coupled with the connection module **601** in the LED driver **600**.

FIG. **15** is a perspective view of an LLT lamp **900** that adopts a readily retrofittable mechanism with a lens (not shown for clarity). FIG. **16** is a block diagram of a double-ended LLT lamp **900** with shock protection switches and the readily retrofittable mechanism. Referring to FIGS. **15** and **16**, the lamp **900** is for double-ended application with double shock-protection switches in both lamp bases **550**, in which two switch actuation mechanisms **905** are shown. The soldering joints **152** and **153** on the LED PCB **205** (as shown in FIG. **5**) are replaced with a combination of the connection modules **601** and **701** electrically connected to deliver DC power from the LED driver **600** to the LED PCB **707** for LED arrays **706** to emit light. Two lamp bases **550** are respectively attached to the two ends of the LLT lamp housing **802** to form the lamp **900** as a stand-alone lighting device. Each lamp base **550** has an end cover **502** comprising a bi-pin with two pins **509** protruding outwards through the end cover, and the core assembly **500** comprising a mechanical securing means (such as a dowel **511**) to secure the LED driver **600**, wherein: when

the lamp base **550** with the core assembly **500** with the LED driver **600** secured thereon is fixed to the LLT lamp housing **802** on which the LED PCB **707** is fixed, the LED lighting board **700** (or LED PCB **707**) is electrically connected to the LED driver **600** through the linkage **670** of the mechanical securing means (namely, by mating between the dowel **511** and the hole **606** in the LED driver **600**). In FIG. **16**, two shock protection switches **983**, one each in the two core assemblies **500**, are shown. Two pluggable wires **515** connecting the LED driver **600** to the connection terminals **514** on the shock protection switches **983** are also shown. Therefore, as the AC power is delivered to the lamp **900** with the shock protection switches **983** actuated, the LED arrays **706** can emit light.

FIG. **17** is a block diagram of a double-ended LLT lamp **910** adopting the readily retrofittable mechanism. The functions are almost the same as the double-ended LLT lamp **900** with shock protection switches except that the shock protection switches **983** are not used in the double-ended LLT lamp **910**. Two core assemblies **500** are included, one each in the two lamp bases **550** for one connection terminal **514** to be secured therein. The AC power pluggable wires **515** can be easily plugged onto the connection terminal **514** through the hole **512** of each core assembly **500** and make electrical connections so that the AC power can be delivered.

FIG. **18** is a block diagram of a single-ended LLT lamp **920** adopting the readily retrofittable mechanism. The functions are almost the same as the double-ended LLT lamp **900** except that the power is delivered from one bi-pin at one of the two ends of the lamp **920**. In this case, the only core assembly **500** have two connection terminals **514** secured therein for the AC power pluggable wires **515** to be easily plugged in and make an electrical connection with the two connection terminals **514** so that the AC power can be delivered.

Whereas preferred embodiments of the invention have been shown and described, it will be realized that alterations, modifications, and improvements may be made thereto without departing from the scope of the following claims. Another readily retrofittable mechanism in an LLT lamp using various kinds of combinations to accomplish the same or different objectives could be easily adapted for use from the present invention. Accordingly, the foregoing description and attached drawings are by way of example only, and are not intended to be limiting.

What is claimed is:

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

a housing having two ends and a platform between the two ends;

a light-emitting diode printed circuit board (LED PCB) fixed on top of the platform, the LED PCB having a plurality of LEDs and a first connection module fixed thereon;

an LED driver for powering the plurality of LEDs on the LED PCB, the LED driver having two inputs, an LED driver PCB, and a second connection module fixed on the LED driver PCB; and

a first and a second lamp bases for respectively fixing to the two ends of the housing, each lamp base having an end cover comprising a bi-pin with two pins protruding outwards through a side of the end cover, and a core assembly, wherein the bi-pin of each lamp base is electrically connected to one of the two inputs of the LED driver through the core assembly,

wherein the core assembly of the first lamp base further comprises a mechanical securing means for securing the LED driver in place;

wherein:

when the first lamp base with the LED driver secured by the mechanical securing means is fixed to the housing, the second connection module is directly coupled with the first connection module so that the LED driver PCB is electrically connected to the LED PCB; and

when the first lamp base with the LED driver is separated from the housing, the two connection modules are uncoupled and the LED driver PCB is electrically disconnected from the LED PCB.

2. The linear LED tube lamp of claim **1**, wherein when the first lamp base with the LED driver secured by the mechanical securing means is fixed to the housing, the first connection module and the second connection module are directly coupled through mating of the two connection modules.

3. The linear LED tube lamp of claim **1**, wherein the core assembly of each of the lamp bases further comprises an AC power connection terminal, and the bi-pin of each lamp base is electrically connected to the AC power connection terminal that is electrically connected via a wire to one of the inputs of the LED driver.

4. The linear LED tube lamp of claim **3**, wherein each AC power connection terminal is disposed in a hole of the respective core assembly, and the wire is pluggable to the hole of the respective core assembly to make contact with the AC power connection terminal.

5. The linear LED tube lamp of claim **1**, wherein the mechanical securing means is a dowel or a tap hole with a fixing screw, and the LED driver PCB has a matching hole for coupling with the dowel or the fixing screw.

6. The linear LED tube lamp of claim **1**, wherein the mechanical securing means is a retaining clip, and the LED driver PCB has a hole for holding the retaining clip.

* * * * *