SYSTEM FOR DRIVING A PLURALITY OF HIGH POWERED LED UNITS

FIELD OF THE INVENTION

The present invention relates to a system for driving a plurality of high-powered light emitting diodes (LED) units. The device is particularly suitable, but not limited for use in high powered LED light units such as down lights, T5, T8, Light Troffer, Hi-Bay lamps and MR16 light bulbs etc.

BACKGROUND TO THE INVENTION

The following discussion of the background of the invention is intended to facilitate an understanding of the present invention. However, it should be appreciated that the discussion is not an acknowledgement or admission that any of the material referred to was published, known or part of the common general knowledge in any jurisdiction as at the priority date of the application.

Conventional lighting systems typically have a configuration where light products used in the systems are individually driven. For example, a light product such as a down light lamp has its own in-built driver so called a ballast that converts incoming AC electrical supply to higher AC voltage and desired current that is required to ignite then excite the gases (referring to CFL light) thus for lighting up of the down light. Examples of such other light products include T5, T8, Light Troffer, High-Bay lamps, street lamps and flood lamps.

Similarly, when Light Emitting Diodes (LEDs) were introduced in lighting systems, the configuration adopted for LEDs was based on the configuration of conventional lighting systems. Therefore, each LED light unit such as a LED down light has its own in-built LED driver that converts the incoming AC supply to DC voltage and current to light up the LED down light. This means that each LED light unit that is present in a lighting system has an accompanying controller circuit dedicated to that particular LED light unit for converting the incoming AC supply to DC voltage and current for lighting up that particular LED light unit. Hence, if there is a chain of ten

LED down lights in a lighting system, ten LED controller circuits for the entire lighting system are required.

A prior art LED light unit and system is as illustrated in Fig. 1 and Fig. 2 respectively. The LED lamp unit comprises an AC source supply via AC Input Terminal 4, an AC-DC LED driver 3, a LED light/lamp module 4 and heat sink 2.

When connected, the AC supply current will flow to the input of the AC-DC LED driver 3, the AC supply current will be rectified and via switch mode power supply circuitry design in the AC-DC LED driver 3 to supply the desired DC voltage and current to the LED light module 4, thus switching on the LED light module 4. During continuous light-up operation, as heat will be generated by both the AC-DC LED driver 3 and the LEDs device on the LED light module 4, introduction of heat sink 2 is important to ensure the heat generated along the light-up operation is drawn from the heat source and dissipated accordingly. As the LED lighting unit is a combination of AC-DC LED driver 3 and LED light module 4, the heat sink 2 has to account for heat dissipation from both the LED light module and AC-DC LED driver. Consequently, if at any time along the light-up operation the heat sink 2 reaches its maximum heat dissipation capability due to the design limitation in size for standard form factor for the particular LED lighting unit fulfillment will lead to the degradation of light performance and product life span.

The above-mentioned configuration has several disadvantages listed as follows:

- As each LED light unit requires its own in-built controller circuit 3 for lighting up, when the LED light unit is in continuous operation, considerable heat will be generated by both the LED and controller circuit. To moderate the heat, heat sink(s) must be present in each LED light unit for drawing the heat from the heat source and dissipating the heat to the surroundings so as to provide a thermally cool environment for the LED and controller circuit to operate in. It is important that the LED and controller circuit operate in a thermally cool environment because this will reduce power loss and hence improve efficiency. However, due to standard form factors, there is a limit as to the size of the heat sink in each LED light unit. As there are two heat generating

sources in each LED light unit (i.e. the LED lamp unit and the LED controller), the heat sink 2 typically reaches its maximum heat dissipation capability during continuous operation where considerable heat is generated. Consequently, this will lead to the degradation of the LED light unit's light performance and product life span.

- It is typically costly to manufacture LED light units which have built-in controller circuits and heat sinks 2 as they increase the number of components that are needed for manufacture. Furthermore, the heat sink must also be designed to cope with the dissipation of heat from two heat sources with the constraints on its size due to standard form factors. This further increases the overall cost of producing the LED light units.

- As the AC supply will be converted to DC voltage and current in the LED light units by the controller circuits 3, there will be safety related issues that must be addressed. Hence, the LED light units will have to be designed such that they meet the standard safety requirements and size limitations imposed by standard form factors.

Therefore, it is an object of the present invention to overcome, or at least alleviate, the aforementioned problems.

SUMMARY OF THE INVENTION

In accordance with a first aspect of the present invention there is a system for driving a plurality of high powered LED units, the system comprising a single driver for providing approximately ripple free constant DC current to a plurality of high powered LED lamp units, wherein for each high powered LED lamp unit there is provided a heat sink shaped and configured to dissipate heat away from the high powered LED only.

Preferably, the single driver operates in an isolated alternating current fly back configuration having an inductive element as a transformer isolating the plurality of high powered LEDs at the secondary end of the transformer. The single driver may comprises at least an Application Specific Integrated Circuit (ASIC) for detecting and

computing the duration of the energy discharged by the core of transformer to the plurality of high powered LEDs to regulate and provide the approximately ripple free output DC current.

Preferably, the ASIC is programmed to receive feedback at each clock-cycle based on the duration of the energy discharged by the core of the transformer as an input to determine the amount of ripple free constant DC current at the next clock-cycle.

Preferably, the ASIC is programmed to provide a voltage waveform to turn an electronic switch on and off at each clock-cycle.

Preferably, each of the plurality of high powered LED lamp units is in series with the other high powered LED lamp units.

Preferably, the single driver is electrically connected to a dimmer circuitry for adjusting the brightness of the plurality of high powered LED lamp units.

Preferably, the dimmer circuitry is a potential meter, infra-red interface, motion sensor or ambient sensor.

Preferably, where the single driver operates in an isolated alternating current fly back configuration having an inductive element as a transformer isolating the plurality of high powered LEDs at the secondary end of the transformer, the secondary end of the transformer is electrically connected to a short circuit protection circuit.

Preferably, the ASIC is coupled with active power factor controller. More preferably, the ASIC is of a 14-pin configuration. Such a configuration enhances ripple free and constant current feature.

BRIEF DESCRIPTION OF THE DRAWINGS

The following invention will be described with reference to the following drawings of which:

Fig. 1 is a perspective side view of a prior art LED lamp unit with driver and heat sink;

Fig. 2 is a system configuration of the 'one driver one lamp unit' configuration of the prior art LED lamp system;

Fig. 3 is a system view of a 'one driver multiple lamp units' or 'string configuration' in accordance to an embodiment of the invention;

Fig. 4 is a circuit diagram of the LED driver circuit in accordance with a preferred embodiment of the invention for isolated alternating current (AC) application;

Fig. 5 is a table summarizing the use of the invention on a plurality of MR 16 LED lamp as compared to the prior art system; and

Fig. 6 illustrates simulation result of the ripple free constant DC current based on a MR16 load.

Other arrangements of the invention are possible and, consequently, the accompanying drawings are not to be understood as superseding the generality of the preceding description of the invention.

DETAILED DESCRIPTION OF THE INVENTION

In accordance with an embodiment of the invention there is a LED driver **10** for driving a string of high powered LED lamps **100** as illustrated in Fig. 4. LED driver **10** is particularly suited for an isolated alternating current (AC) application and is divided into a primary side and a secondary side. The primary side of the LED driver **10** is decoupled with the secondary side via transformer **11**. The primary side comprises an electronic switch **14**, bridge rectifier **16**, and an Integrated Circuit (IC) controller **18**.

To satisfy its decoupling function, transformer **11** is an isolation transformer, and may preferably be a planar transformer.

Resistor $\mathbf{R_P}$ and capacitor $\mathbf{C_P}$ are connected in a parallel configuration with the primary end of the transformer **11**. A diode $\mathbf{D_P}$ is connected to the Resistors $\mathbf{R_P}$, capacitor $\mathbf{C_P}$, and the transformer **11**. The conducting end of the diode $\mathbf{D_P}$ is connected in a series configuration to the primary end of the transformer **11**. The non-

conducting end of the diode $\mathbf{D_P}$ is connected in series configuration to the resistor $\mathbf{R_P}$ and capacitor $\mathbf{C_P}$.

A capacitor $\mathbf{C_S}$ is connected in parallel to the secondary end of the transformer **11**. A diode $\mathbf{D_S}$ is connected to the secondary end of the transformer **11** and the capacitor $\mathbf{C_S}$. The conducting end of the diode $\mathbf{D_S}$ is connected to the secondary end of the transformer **11** in a series configuration. The non-conducting end of the diode $\mathbf{D_S}$ is connected to the capacitor $\mathbf{C_S}$ in a series configuration. The LED load **100** is connected in a parallel configuration to the capacitor $\mathbf{C_S}$. Each LED load **100** may be connected in series with the other LED load **100**.

Electronic switch **14** is typically a power transistor. In this particular embodiment, electronic switch **14** is a MOSFET. In the MOSFET configuration, the drain of the electronic switch **14** is connected to the conducting end of the diode $\mathbf{D_P}$ and to the primary end of transformer **11**. The gate of the electronic switch **14** is connected to the output pin of the IC **18**, and the source of the electronic switch **14** is connected to the electrical ground.

The IC controller **18** comprises an internal oscillator and is configured to turn on the gate of the electronic switch **14** with a particular turn-on time period T_{ON} for each clock cycle as determined by the oscillator. IC controller **18** is preferably an Application Specific Integrated Circuit (ASIC) programmed to sense and obtains the discharge time of the inductive element L_1 and L_2 as a main input. ASIC **18** is programmed and configured to turn on the gate of the electronic switch **14** having a turn on period of T_{ON} at each clock cycle based on the following inputs:-

(a.) A reference constant **K** based on the discharge time of the inductive element L_1 and L_2;

(b.) Desired output current for LED $\mathbf{I_{OUT}}$;

(c.) A digitized voltage value $\mathbf{V_{DD}}$ tapped and digitized from potential divider **22**, the potential divider **22** connected in parallel with the bridge rectifier **16**;

(d.) A time value $\mathbf{T_{OFF}}$ of the discharge of the core of transformer **11** measured through voltage potential divider **30** and compared to a reference voltage; and

(e.) The switching period **T** (i.e. the switching period of the electronic switch **14** as determined by the oscillator).

Using the received five inputs, the IC **18** computes an output $\mathbf{T_{ON}}$ which is the switch on time of the electronic switch **14** in accordance with formula 1.

$$T_{ON} = \frac{I_{out} * T}{K * V_{in} * T_{off}} \quad (1)$$

The reference constant **K** is calculated based on the inductance value of the primary and secondary windings of the transformer **11** as described in formula 2.

$$K = \frac{1}{2 * \sqrt{L_1 * L_2}} \quad (2)$$

where L_1 is the inductance value of the primary windings of the transformer **11** and L_2 is the inductance value of the secondary windings of the transformer **11**. The value of reference **K** may be stored in a memory within the IC **16**.

Manipulating equation (1) and (2), I_{OUT} is derived as follows:-

$$I_{OUT} = \frac{V_{IN} * T_{ON} * T_{OFF}}{2 * \sqrt{L_1 * L_2} * T} \quad (3)$$

The IC controller **18** may further comprises a dimming pin coupled to a variable resistor **40** for performing dimming on the LED load **100**. The dimming pin further facilitates the flexibility to perform dimming via various dimming device such as potential meter, motion sensor or Infra-red sensor.

To increase the control capabilities, an ASIC having higher resolution may be used e.g. 14-pin configuration which translate to 10 Bits. The ASIC may further be coupled to active Power Factor Controllers (PFC) to improve its power factor.

At the secondary side, the LED driver comprises a voltage protection circuit **44**. Voltage protection circuit **44** comprises a zener diode **46**, a silicon controlled rectifier (SCR) **48** and a resistor **50**. When a short circuit is detected, the zener diode **46** will conduct electricity thus enabling the SCR **48** and reducing the output voltage to the LEDs **100**.

The LED driver **10**, in the context of operation of driving a string of LED light units, will be described in the following example:-

To operate the circuit, the variable resistor V_R is first adjusted to produce a value N, where value N is an adjustment of turn on time period T_{ON} of the electronic switch **14** corresponding to the generation of the maximum approximately ripple-free constant current to drive a plurality of LED lamp units **100**. The decrement or increment of adjustment N value will be based on the feedback and cause changes in T_{ON}, T directly, thus varying I_{OUT} accordingly based on the variable resistor V_R to dim or brighten the LED lamp units **100**.

Depending on the number of lamp units **100** and the desired current I_{OUT}, a user merely needs to perform minor design optimization by changing few critical components as follows:-

Inductance $\mathbf{L_1}$ and $\mathbf{L_2}$ of the transformer **11** and switching frequency, $\mathbf{V_{DS}}$ Drain-Source Voltage and $\mathbf{I_D}$ Drain current of the MOSFET **14**, capacitance value of Capacitor $\mathbf{C_S}$ and Diode $\mathbf{D_S}$ to the correct rated components to adopt each specific output load requirement. Care must be taken to ensure that voltage across capacitor $\mathbf{C_S}$ voltage should be higher than the voltage of the LED load **100**. The diode's forward current I_F and repetitive peak reverse voltage V_{RRM} are also parameters to consider for the diode changes.

The controller **18** detects and computes the duration of the energy discharged by the core of transformer **11** to the LED loads **100** to regulate the constant output current. Therefore, the controller **18** can work on a wide range of load voltage and constant current for high powered LED lights **100**.

The described embodiment provides for an approximately ripple free constant DC current to the plurality of high powered LED lamp units **100**. The described configuration of one driver to multiple lamps is termed by the applicant as 'string configuration'.

The described embodiment based on the a single LED driver **10** to drive many high powered LED lamp units **100**, each high powered LED lamp unit provided with a heat sink shaped and configured to dissipate heat away from the high powered LED only and the single driver configured to provide approximately ripple free constant DC current to the plurality of high powered LED lamp units has been compared with a prior art MR 16 system where one LED driver **3** is required for each LED lamp unit **4**. This standard ASIC driver design solution drive in constant current and offer a wide range of flexibility to drive a series of any numbers of LEDs within the entire lighting system, the advantages of which are summarized in Fig. 5.

Fig. 6 is an I_{OUT} measured from a high powered LED load **100** illustrating the extent of ripple free constant DC current.

In addition, the following advantages are also apparent:-

a. Safer Methodology for LED Lighting Unit

As the LED driver 10 is an isolated DC configuration and only work with DC driven LED lighting Unit, there will be no safety related issue associated with AC currents for the LED lighting units 100 which are at the secondary side and isolated from the mains. Further, as the LED driver 10 will be isolated from the LED lighting unit 100 hence there will be not size limitation on the design as in build in configuration so the LED driver 10 can be designed in accordance to safety requirement.

b. High Electrical Efficiency

The LED Driver 10, also termed string driver, operates in thermally cooler environment because it is not affected by the heat dissipated by the LEDs unit 100 during the continuous power on operation. The thermally cooler operation environment will reduce thermal loss on the LED driver 10 hence less power is

consumed during operation to improve efficiency. Compared to the prior art, where each LED lamp comprises its own driver which is directly connected to the AC mains, power efficiency will be significantly improved compared to AC driver lighting unit in a complete lighting system because total power losses only apply to the particular single driver whereas AC driven lighting unit will having higher total power loss due to losses on each lighting.

c. High Efficacy (lumens/watt)

String configuration offer cooler operating environment which resulted lower optical loss for the LEDs device hence higher luminous flux exhibited by the LED devices eventually improved the efficacy (lumens/watt) for the entire lighting system.

d. Longer Lifetimes

The LED driver 10, using ASIC control, eliminates the use of short lifetimes components such as Aluminum Electrolytic Capacitor where this is extended the lifetimes of the LED driver 10. As for the LEDs lamp units 100, the thermally cooler and operation with approximately ripple free constant current will improve the performance and reliability of LED devices significantly and slow down the entire degradation progress on the LED device 100 eventually prolong the lifespan for the entire LED lighting unit.

e. Wide Range Application Options

The flexibility design for the single LED driver 10 is applicable for any type of DC driven LED lighting unit and theoretically is able to drive unlimited numbers of LEDs in the entire lighting system by just minor fine tuning the solution components to adapt the output load requirement as described earlier.

f. Cost Effective Solution

String driver configuration is a cost effective solution since single the LED Driver 10 is capable to drive a series of DC driven LED lighting units whereas the prior art configuration require one driver for each LED lighting. Further, the solution also offer

more competitive manufacturing cost as well as design part cost especially for heat sink.

g. Ease of Maintenance

Since the single LED Driver 10 is isolated from the LED lighting unit 100, if any failure occurred within the lighting system that due to a faulty LED driver 10, the user just need to replace the faulty LED driver instead of dismantling the entire LED lighting (Build-in concept) . Such maintenance process is simple and may be completed within a relatively short period.

h. Dimming Flexibility

As LED are current driven devices, the intensity of light they generate depends on the amount of current flowing through them. A wide range of dimming device may be coupled with the IC controller **18** in addition/alternative to the dimmer 40 as described in the embodiment for performing dimming purposes. With string configuration only single dimming device require to control the flowing current and to dim the entire lighting system for dimming purposes. The LED driver design enable the user to dim their LED lighting unit to as low as 1 ~ 2% of the original driving current without any flickering phenomena. The IC controller 18 may further comprise a multipoint control unit (MCU) to enable communication with intelligent control means such as power line, Digital Addressable Lighting Interface (DALI), wireless protocol for total lighting control system.

i. Miniature in Form Factor

The heat sink for the lighting luminaries will be smaller in size where the heat sink just to design to dissipate heat generated by the LED lighting unit 100 where not heat generated from the AC-DC LED driver because of isolating between them. Also the single driver can be design in such an optimized size due to less components count require for the entire system compare to integral concept and thus less material used and the introduction of planar transformer will further enhance the slim look of the driver solution instead of conventional transformer that is in bulky form factor.

It is further apparent that the LED Driver 10 requires less components count and less repetition of components compared to prior art systems where each LED lamp unit requires its own AC to DC driver. The driver solution form factor is thus reduced. Besides that, manufacturing process will be simplified such that production throughput and yield rate will be improved.

It is further apparent that the heat sink form factor for each LED lighting unit 100 will be reduced in the string configuration because the each heat sink will be required to only handle the heat distributed by the LED lighting unit 100. This is because the LED driver 10 is isolated from the LED lighting unit 100. This will beneficial on part cost due to less material utilization. Furthermore, the entire design cycle will be further shorten since both LED lighting unit 100 and LED driver 10 design activity can be carried out simultaneously that leads to improve product time to market.

CLAIMS

1. A system for driving a plurality of high powered LED units, the system comprising a single driver for providing approximately ripple free constant DC current to a plurality of high powered LED lamp units, wherein for each high powered LED lamp unit there is provided a heat sink shaped and configured to dissipate heat away from the high powered LED only.

2. A system according to claim 1, wherein the single driver operates in an isolated alternating current fly back configuration having an inductive element as a transformer isolating the plurality of high powered LEDs at the secondary end of the transformer.

3. A system according to claim 2, wherein the single driver comprises at least an Application Specific Integrated Circuit (ASIC) for detecting and computing the duration of the energy discharged by the core of transformer to the plurality of high powered LEDs to regulate and provide the approximately ripple free output DC current.

4. A system according to claim 3, wherein the ASIC is programmed to receive feedback at each clock-cycle based on the duration of the energy discharged by the core of the transformer as an input to determine the amount of ripple free constant DC current at the next clock-cycle.

5. A system according to claim 4, wherein the ASIC is programmed to provide a voltage waveform to turn an electronic switch on and off at each clock-cycle.

6. A system according to claim 1, wherein each of the plurality of high powered LED lamp units is in series with the other high powered LED lamp units.

7. A system according to claim 1, wherein the single driver is electrically connected to a dimmer circuitry for adjusting the brightness of the plurality of high powered LED lamp units.

8. A system according to claim 7, wherein the dimmer circuitry is a potential meter, infra-red interface, motion sensor or ambient sensor.

9. A system according to claim 2, wherein the secondary end of the transformer is electrically connected to a short circuit protection circuit.

10. A system according to claim 3, wherein the ASIC is coupled with active power factor controller.

11. A system according to claim 3, wherein the ASIC is of a 14-pin configuration.