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AC LEDs- Current and Future Technology Trends

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ABSTRACT *Light Emitting Diodes (LEDs) are rapidly replacing conventional incandescent and HID light bulbs. Different types of LEDs and drivers are developed, to meet different objectives. One factor that dominated the innovations in LEDs is the relative advantages of DC and AC drivers. No driver is perfect and each driver has its own tradeoffs. The innovators are focusing on obtaining better efficiency and cost effectiveness. The future trends in innovations include improvement in semiconductors, drivers that are more efficient, better thermal packaging, integration with IoT, and integration with renewable energy sources.*

KEYWORDS : AC LED's DC LED's, Diodes, Organic LED's HBLED's, IoT, LI-FI

LED Types

Light Emitting Diodes (LEDs) are small and multiple point light sources, which are rapidly replacing conventional incandescent and HID light bulbs. Due to their unique form factor, they give the lighting designers enormous freedom for selecting various shapes and sizes for their light engines and form a major part of the residential and commercial lighting. They also allow better control of the overall light distribution, which results in visible improvement in the light uniformity [1]. LEDs also have high-energy efficiency for the total lumen output. Although their applications range from the light bulbs, strip lights to television display at the core they are mainly of three types [2]. They are traditional inorganic LEDs, organic LEDs and high brightness LEDs.

Traditional inorganic LEDs have been around since the 1960s, with compound semiconductors being the more popular examples. However, there are many unique styles of LEDs with different purposes. These LEDs can be either single color 5 mm LEDs, surface mount LEDs, bi-color and multicolor LEDs, or flashing LEDs.

Organic LEDs (OLEDs) are similar to traditional LEDs, with the main difference being that they are made of only organic compounds such as Aluminum 8- hydroxyquinoline or diamine. OLEDs have several benefits including flexibility, being very thin, having high color capability, low power consumption, bright images, a wide viewing angle, fast response time, and future low cost.

HBLEDs are inorganic LEDs, similar to the traditional LEDs, but with a much larger light output. They must handle a high current and are usually installed onto heat sinks to excise the unwanted heat. Recently, LEDs are being manufactured in surface mount packages. Various sizes and lumen outputs are available from such LEDs. They have high efficiency and low cost compared to their through-hole counterparts. The good part of the surface mount technology is that the heat dissipation of the LEDs is better and better color combinations are possible since multiple LEDs are manufactured in to a single package. This also allows the LEDs to have a finer control since it is possible to control each LED, individually.

DC or AC Drive?

Regardless of their type, LEDs are basically diodes and need a DC current to operate. In the past, researchers and LED developers, used switched mode power supply based techniques to drive the LEDs. This approach uses a cascade connection of a diode rectifier, power factor correction circuit and constant current DC to DC converter circuit. The diode rectifier converts the AC voltage in to DC voltage. To ensure very high power factor while driving the LEDs, an active power factor correction circuit based on the boost converter is used after the rectifier. This circuit gives a constant DC voltage. This DC voltage is converted in to a constant DC current passing through the LEDs by another DC to DC converter. This method gives very precise control on LED properties such as flicker control and dimming and has higher efficiency than the AC drivers. Sometimes, the active power factor correction circuit and the LED current control circuit are combined into a single switching stage. This drive technique uses so many electronic components and the overall cost and sizing of the LEDs was always an issue. This issue led to the new concept of AC LED drivers. In its simplest form, the AC led driver consists of two parallel-connected LED strings with the series forward voltage equal to nominal AC voltage [3] as shown in Fig.1 (a). However, this method leads to a highly inefficient operation. Since only half of the LEDs conduct at any given time, this method resulted in twice the die size. So engineers came up with the circuit shown in Fig. 1(b) where a bridge rectifier is connected, before the LEDs. This configuration increases the efficiency significantly. This circuit is cheap; it does not need any power factor correction circuits or EMI.

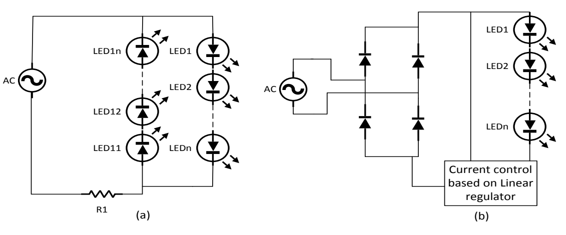

Figure 1 AC LEDs basic driving schemes (a) One string conducts in one cycle (b) LED string conducts all the time

However, the method in Figure 1 (b) has issues such as voltage fluctuations, resulting in LED current and power fluctuations, leading to lower LED life. Besides the problem of low LED life, the AC LEDs also have a very large low frequency flicker. The sinusoidal current, instead of constant current, passing through the LEDs causes the low frequency flicker. Table 1 compares the DC and AC LEDs on various parameters.

Table -1
Comparison of AC LEDs and DC LEDs

AC LEDs	DC LEDs with driver
Direct AC drive with a current regulator	High reliability with regulated current (Switched mode power supply approach)
Ultra low initial cost with and without dimming (5Rs/watt)	Higher initial cost (10 to 15 INR/Watt)
No tolerance to AC line voltage fluctuations	High tolerance to the line fluctuations and accepts a wide AC input voltage range
High flicker	close to zero flicker
Low power rating due to losses in the regulator	High power can be easily achieved
Easy packaging in various shapes and sizes due to less number of components	Packaging is challanging due to less number of components

Current Technology

As seen from Table -1, no driver is perfect and it has its own tradeoffs. However, in most of the applications, cost is the driving factor for all the development. This makes the AC drive technology an obvious choice. To obviate the flicker and efficiency issues, AC LED technology has been evolving at a rapid pace in many different directions. Some of the main technology areas are LED semiconductors, electronics topology and also smart communications.

Semiconductor

Most of the AC LEDs are going towards a high level of integration. Companies like Seoul semiconductors and Lynk labs [4,5] have integrated the rectifier and current controller on one IC along with the LEDs. The control of LED current is done in definite steps as per the AC voltage and current changes in the cycle. Therefore, manufacturing LED lightbulbs is much easier as no additional hardware is required. Other manufacturers have taken a more generic approach where they have developed the drivers which can suit different LEDs with different power ratings. For example, TI AC LED driver [6] uses semiconductor switches along with their drivers to direct the current or bypass the current in the LED stack. This approach enables use of capacitors for the low AC voltage condition, which reduces the flicker and also gives a flexibility in the design. Fairchild uses [7] an intermediate approach wherein, the controller and LEDs are not integrated in one unit. Still, there is only one controller, which drives different LED strings. It does this by taking the input from the dimming and current sense circuit. In most of the integrated approaches, thermal protection is built into the controller IC.

Electronic topology

To reduce the flicker, various topologies are being created. One of the most promising approaches uses a bridge rectifier [8] and obtains a pulsating DC voltage. This DC voltage is applied to the control module and the LEDs. The control module, based on the feedback signal and the information received from the dimming circuit, switches electronic switches in such a way that the input current follows the input voltage. This approach is shown in Fig. 2.

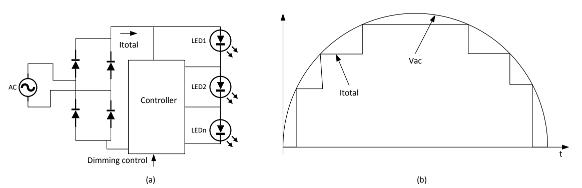

Figure 2 Current using switching network and controller (a) Topology (b) Current waveshape

In another approach shown in Figure 3(a), a low frequency boost converter has been used [9] to control the current in the LED driver. In this method, a single pulse is used at twice the AC line frequency in a boost circuit. The boost circuit controls the LED current and complies with the current harmonic regulations. It also has another advantage of no electrolytic capacitors and ultra-low cost with high power factor. In another method, buck converter topology has been used for driving multiple LED strings. For example, the approach shown in Figure 3(b) uses a single switching stage [10] to control the power factor and current regulation instead of using another LED current regulator stage. Multiple switches are used to control the current in the different LED strings with a single inductor. The switches are switched in a time multiplexed manner and save the switching loss to a significant extent. Since both the operations are combined in a single switching stage, the need for an electrolytic capacitor is eliminated and the drive is similar to an AC LED drive.

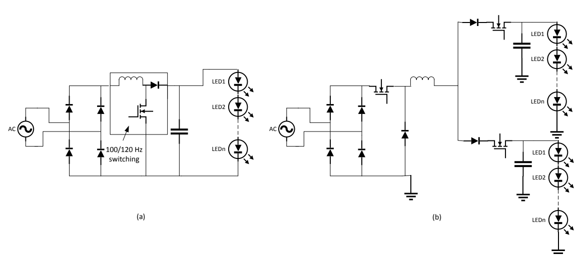

Figure 3 (a) Low frequency boost converter for LED current control (b) Buck converter driving multiple LED strings

In one of the most recent approaches, multilevel converters are being developed to increase the voltage of the LED stack and hence reduce the effective current flowing in the LEDs. The main difference between this approach and other previous approaches is that since the LED stack voltage is much higher than the mains voltage, all the LEDs are connected in the series as against in parallel. This approach increases the driver efficiency to above 95% and also eliminates the problem of current sharing between different LEDs. This has a tradeoff of higher safety and isolation requirements [11].

Smart Communication

Besides the LEDs and the drive topology, numerous attempts are being made to make LEDs smarter. Most common techniques in the market today use LED controls based on either mobile phone or other smart devices, which control the power, temperature and dimming of the LEDs. In [12], a Bluetooth communication circuit has been integrated on the LED driver. Since this communication protocol is extremely generic, lighting manufacturers can directly install the light engines and develop communication software to control them. Additional sensor installation is also possible to improve the effective energy use. This goes very well with the Internet of Things (IoT) where the LEDs can directly talk to the ambient sensor and dim accordingly.

Optical communication (Li-Fi): Li-Fi or light fidelity has started a new era in LED lighting. It is a highspeed communication based on the optical signals. Although there have been attempts to use this communication in the research [13], PureLi-Fi had [14] the first commercial success with this technology. This communication is based on the visible light spectrum. A high frequency communication signal is superimposed on to the LED along with the main power. This results in modulating the LED power at a very high frequency unnoticeable to the human eye. A light receiver placed at the other end intercepts these signals and completes the communication network. The main advantage of this type of communication is that it does not interfere or use electromagnetic spectrum, so that it can be used in places where electromagnetic waves can interfere with the system operation. It is also a highly secured form of communication since the light does not penetrate through the walls. The Li-Fi also has a health related dimension. In the developing countries, the mobile phone towers are placed in densely populated areas and generate a lot of electromagnetic pollution. This pollution causes severe health hazards. Li-Fi would serve a good alternative or compliment the traditional communication in such places.

Disney research [15] has given another angle to the LED based communication. They have used photodiodes in combination with LEDs to send as well as receive the data on the light spectrum. This enables two LEDs to communicate with each other directly without any intermediate device. This communication ability has the potential to revolutionize the communication world completely.

What Next?

Semiconductor Improvement

In most of the AC LED drivers, implementation of true universal AC input voltage has been a challenge for quite some time. There have been some attempts by companies like LuxTech [16] but seamless universal AC control is yet to be achieved. In developing countries like India, where the voltage fluctuations are huge, the driver with this ability has huge potential. Besides the universal AC input voltage, one of the needs for the developing countries is protection against sustained high input voltage. Sometimes the LEDs are subjected to frequent line voltage faults, which exposes them to much higher voltage than the nominal input AC voltage. An integration of a high voltage protection circuit with the AC driver can increase the reliability of the AC drivers significantly.

High Efficiency Drivers

Most of AC LED drivers still suffer from low efficiency. Future LEDS will be driven by more and more efficient driving techniques to break the 95% efficiency barrier. Improved power electronics devices along with the advances in the digital control can make this possible.

High Efficiency Thermal Packing

Today most of the LED lighting have inefficient thermal packaging of the electronics. Newer materials for the heat sink are being used, which improve the thermal conductivity of the LED fixtures significantly and keep the LED and electronics at much lower temperature. Future LED fixtures can use materials like engineered sand [17] to have a very efficient cooling.

Integration with IoT

Sensor technology with wireless connectivity has been developing swiftly. LEDs can be easily integrated into the network of smart sensors. LEDs can directly communicate with other devices in the residential or commercial space and improve its usage and life.

Integration with Renewable Energy

With the recent developments in distributed PV based electricity generation, small generators can be integrated with LEDs to drive them independent of grid power. Figure 4 shows one of the future LED integrations with the PV energy. The PV panels generate electricity to power the LEDs using some storage medium. The LEDS then use this energy and use it to light up the streets in the form of streetlights and create wireless hotspots. When this integration is used for indoor applications such as airports or train stations, LEDs with the ability to communicate can take part in implementing smart grid protocols with PV energy.

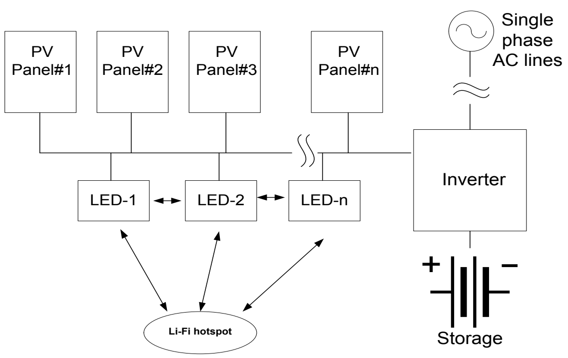

Figure 4 Renewable energy integration with LED systems

Conclusion

LED space is about to witness many technological advances in the near future. The innovations that seek to achieve better efficiency and more integration with other technologies will make the LEDs increasingly energy and cost efficient.

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