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ORIGINAL ARTICLE

# A single-stage voltage sensorless power factor correction converter for LED lamp driver

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Received 23 April 2013; revised 16 July 2013; accepted 18 July 2013

Available online 20 August 2013

## KEYWORDS

LED lamp;  
PFC;  
Total harmonic distortion (THD);  
Voltage sensorless;  
Zero-crossing detector

**Abstract** Light-emitting diode (LED) technology presents an effective and robust solution to decrease the energy demand. In this paper, a power factor correction (PFC) converter is proposed to solve the problems that appear when using LED lamps, such as reducing harmonic currents and reshaping the input current to be a sinusoidal waveform without using line voltage sensor, so the total cost can be reduced and increasing the efficiency. Thus, this technique is considered a simple and easy method which reduces the number of sensors required and achieves the noise isolation between the power circuit and the controller. Also, the proposed method is implemented using a zero-crossing processing, which allows a greater accuracy than other methods. Simulation and experimental results demonstrate the effectiveness and feasibility of the proposed circuit which show that the proposed control method has low inrush input current, high power factor (near unity), and fast dynamic response under transient operation. Also, a sinusoidal current waveform under a non-sinusoidal input voltage condition can be achieved.

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## 1. Introduction

While Edison is credited with the development of the first commercially practical incandescent lamp in order to improve the lifestyle, conventional lighting sources have low efficiency and high energy consumption [1]. One of the key motivations for the recent development in LED lighting is the possibility for increasing efficiency and light output. LEDs are gradually replacing the conventional lighting sources due to their numerous advantages such as [2–4]:

- High efficiency which can emit more light per watt than incandescent lamps.

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Peer review under responsibility of Faculty of Engineering, Alexandria University.



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### Nomenclature

$R$	ideal resistance	$V_{ref}$	reference voltage
$L$	boost inductor	$v_{control}$	the controlled scaling factor of the rectified voltage
$D$	diode	$V_{rms}$	RMS value of the input voltage
$S$	MOSFET (Switch)	$V_o$	load voltage
$V_s$	supply voltage	$V_{o(mean)}$	mean load voltage
$i_s$	supply current	$I_o$	load current
$V_{in}(t)$	the rectified voltage	$V_F$	forward voltage drop for LED lamp
$\hat{V}_{in}(t)$	the estimated input voltage	$\omega_{line}$	angular line frequency
$i_l$	inductor (rectified) current		
$i_{ref}$	reference current		

- No ultra-violet (UV) or infrared (IR) output.
- Have a relatively long useful life, c. 100,000 h which is more than 10 times that of compact fluorescent lamps (CFLs).
- Can very easily be dimmed either by pulse-width modulation or lowering the forward current.
- LED lamp module is composed of many LEDs, when one LED fails there are many more for back-up.
- They can be dimmed smoothly from full output to off.
- Extremely robustness, those are difficult to damage with external shock, unlike conventional lamps, which are fragile.
- Small in size.
- No external reflector.

Like conventional PN junction diodes, LEDs are current-dependent devices with their forward voltage drop  $V_F$ , depending on the semiconductor compound (their light color) and on the forward biased LED current. Fig. 1 presents the  $I$ - $V$  characteristic curves showing the different colors available [5].

LEDs are operated from a low voltage DC supply. In general lighting applications, the LED lamps have to operate from universal AC input, so an AC-DC converter is needed to drive the LED lamp [6]. The efficient drive not only performs unity power factor (PF), but also regulates LED current [7].

The rectifier with filter capacitor is called a conventional AC-DC utility interface. Although a filter capacitor signifi-

cantly suppresses the ripples from the output voltage, it introduces distortions in the input current and draws current from the supply discontinuously, in short pulses [8]. This introduces several problems including reduction in available power, and the line current becomes non-sinusoidal which increases the total harmonic distortion (THD) and increases losses. This results in a poor power quality, voltage distortion, and poor PF at input ac mains [9-11].

With the development of PFC converters, a sinusoidal line current can be made in phase with the line voltage, and this PFC circuit achieves the requirements of the international harmonic standards. For all lighting products and input power higher than 25 W, AC-DC LED drivers must comply with line current harmonic limit set by IEC61000-3-2 class C [12]. Single-stage PFC topologies are the most suitable converters for lighting applications, as PFC and regulator circuits can be merged together. They have high efficiency, a near unity PF, simple control loop, and a small size. In reality, the switching frequency is much higher than the line frequency, and the input AC current waveform is dependent on the type of control being used [13]. The inductor is assumed to be operated in continuous conduction mode (CCM) which is implemented using hysteresis current control method. Operation is possible throughout the line-cycle, so the input current does not have harmonic distortions [14,15].

There are various PFC control algorithms using input voltage sensorless approach [16-19]. A simple control method using current law has been described in [16,17] by using only an instantaneous input current and a proportional gain in controlling the dc link voltage constantly. However, these methods did not take in consideration the current compensation, so stable operation in the transition state and protect devices from overcurrent cannot be achieved. Nonlinear-control methods [18,19] provided good solutions to implement the control integrated circuit (IC) design effectively without using input voltage sensor. However, the output voltage regulation will be affected due to lack of input voltage information.

In this paper, boost PFC converter is used to drive LED lamps from universal AC supply due to its advantages such as [20-22]: (a) simple structure; (b) the input inductor can suppress the surging input current; and (c) the power switch is non-floating, so it is easy to design the driver circuit. An algorithm of PFC control is proposed without using line voltage sensor. The input voltage is estimated using the sensed inductor current and output voltage, which make the proposed method more simple and reliable than other methods. Also, a

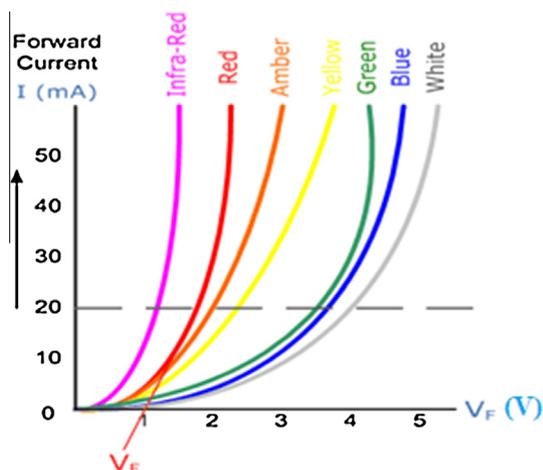


Figure 1  $I$ - $V$  characteristics curves for different colors available.

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