DESIGN OF LED DRIVER CIRCUITS WITH SINGLE-STAGE PF CORRECTION IN DCM

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Abstract— LED driver with constant output current and power factor correction are presented in this paper. The non-isolated Buck converters are used for the LED drivers, according to different operating mode of inductor current, power factor correction is realized with Voltage Follower Control under DCM. The designed circuits are verified by simulations of OrCAD PSpice software, and show that the proposed approaches achieved the goal of higher PF and constant output current.

Index Terms— Buck Converter, DCM, LED Driver, Power Factor Correction.

I. INTRODUCTION

Thomas Edison invented electric lights improving the lifestyle of mankind, however, conventional incandescent lamps suffer from low efficiency and short life span, fluorescent lights and high intensity discharge lamps must operate with ballasts, moreover, HID lamps require much high voltage for ignition and longer time taken from transient to steady state, acoustic resonance constantly occurred, result in arc, optoelectronic output fluctuation and color change, even destroy lighting bulb, therefore, uneasily controlled, light emitting diode(LED) is stiff, small size, high efficiency, durable, rapidly react and environmentally friendly, applying in variant fields and gradually become main stream. Switching power supplies have the advantages of high efficiency, lower voltage and cost, consequently, being widely used, they can be divided into two types, isolated and non-isolated, though isolated types have more safe operation features, an isolated transformer must be implemented. The power factor of conventional switching power supplies generally are low, lower PF reduces efficiency, deteriorates power quality and results in waste of power. The paper focuses on LED drivers with non-isolated Buck converter which are lighter in weight to perform power converting and respectively controlled under different current operation modes, saving the cost of circuits and lifting the power factor are set as the objectives of LED driver power factor design. Buck converters can be subdivided into discontinuous conduction mode (DCM), continuous conduction mode (CCM) and boundary conduction mode depends on the difference of inductor current mode, this research is on voltage follower control under DCM and utilizing simulation software and implemental circuits analyze the advantages and disadvantages, verifying whether these circuits can meet the requirements of contemporary industries.

II. LED DRIVING METHODS

This experiment used 1W white LED, Fig. 1 shows its measured V-I curve, when forward biased greater than cut-in voltage, current and voltage approximate linear relation, this feature can be equalized to a resistive load, here operation point of LED is set at 3.5/350mA, hence, can be equalized to a 10 Ohm resistor, in order to be taken as reference figures during software simulation and experiment. In general, LED driving style can be divided into constant voltage driving and constant current driving; both are by creating forward biased current conduct these elements.

Fig. 2 shows constant voltage driving configuration, providing voltage to LED that connected in parallel, every shunt LED connected in series with a ballast resistor for restraining the magnitude of current which conduct LED, the advantages of this configuration are simpler structure and lower cost. However, LED is sensitive to temperature variation, by observing Fig. 1, when temperature and voltage varied a little bit, forward current will follow along varied a great amount, thus, influence the lighting extraction and further lower stability, for avoiding these drawbacks, constant current driving method that shown in Fig. 3 can be adopted, this method connect in series a resistor at LED’s lead end, by means of resistor current turn into voltage
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of each LED is assumed to be constant 350 mA, forward voltage of 3.3-3.7 Vdc, with equivalent resistance of 10 ohm each as load. The specific parameters of buck converter are given below in table

<table>
<thead>
<tr>
<th>Table 1 – Specification of Buck Converter</th>
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<tbody>
<tr>
<td>Input Voltage</td>
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<tr>
<td>Output Voltage</td>
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<tr>
<td>Output Power</td>
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<tr>
<td>Switching Frequency</td>
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<tr>
<td>Inductor</td>
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<td>Load</td>
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<td>LED</td>
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IV. THE VOLTAGE FOLLOWER PFC

The configuration shown in Fig. 5, is used in low power load, when Buck converters operate in DCM, utilize voltage loop to causes input current following input voltage waveform so as to perform higher PF and more stable voltage.

Using voltage follower method [5] to drives LED load with constant current, LED connected in series with a resistor Rf which for sensing output current, Rf should dissipates as little power as possible, via Rf the output current which sensed in LED transformed into voltage, i.e. output current conducts Rf creating a sensing feedback voltage Vf , after comparing with reference voltage Vref, this signal be sent into an error amplifier and a low pass voltage compensator, yielding a Vc signal afterwards be sent into PWM and compare with constant frequency sawtooth voltage then a signal be formed to modulating the duty of Buck switch, enabling this system to achieve stable output current. Using PSpice software to simulate this configuration that listed in Table I, since voltage follower using a Buck converter which inductor current performs in DCM, hence, utilizing a 150mH inductor to analyze and verify these results, this simulation circuit is shown in Fig. 6. When doing simulation, the load is substituted by LEDs, replacing 12 LEDs (3.5/350mA) with a 120Ω resistor, the variation of input voltage is 42V, the load is replaced with a resistor, the sensing resistor Rf = 1 Ohm hence, the level of reference voltage Vref = 0.35 V. The
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Voltage compensator block consists of a subtractor, low pass filter followed a buffer amplifier. This signal is fed to generate required PWM to switch the MOSFET. This feedback helps to improve the PF and protection of the circuit for over-voltage.

After simulation, Fig. 7 shows various results obtained by the simulation. Fig 7(a) Is tracking Vm, Fig 7(b) reveals waveform of inductor current operated in DCM. 7(c) and 7(d) shows the working of buck converter and Voltage Power respectively.

CONCLUSION

By simulating the suggested circuit it was observed that the power factor is increased when compared to the commercially available LED drivers and can be used for higher load power also. The circuit size is reduced and made easy to assemble.

REFERENCES