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RESEARCH ARTICLE

QUASI RESONANT BUCK CONVERTER FOR DUAL STRING BUCK LED DRIVER

Vijayadevi.A[1], Sneha Prem[2], Jikku Mathew[3], Manikandan.K[4], Sajla Rehman[5]

[1]Department of Electrical and Electronics Engineering, Easa College of Engineering and Technology, Coimbatore, India
vijayadevi.91@gmail.com
[2]Department of Electrical and Electronics Engineering, Easa College of Engineering and Technology, Coimbatore, India
sneha91@gmail.com
[3]Department of Electrical and Electronics Engineering, Easa College of Engineering and Technology, Coimbatore, India
jikkumathew89@gmail.com
[4]Department of Electrical and Electronics Engineering, Easa College of Engineering and Technology, Coimbatore, India
manibekovai@gmail.com
[5]Department of Electrical and Electronics Engineering, Easa College of Engineering and Technology, Coimbatore, India
sajlarehman2008@gmail.com

Abstract—The project presents the digital simulation of Quasi Resonant Converter for driving multiple LED strings using MATLAB Simulink. Quasi Resonant Converter (QRC) is fast replacing conventional PWM converters in high frequency operation. The salient feature of QRC is that the switching devices can be either switched on at Zero Voltage or switched off at Zero Current, so that switching losses are zero ideally. It adopts suitable PWM switching method using resonance. QRC based digitally controlled dual output buck switching LED driver operates in Discontinuous Conduction Mode (DCM) to reduce the input current ripple and extends it to drive multiple outputs. Based on the time multiplexing control scheme in DCM, a theoretical upper limit of the total number of outputs in a buck switching LED driver for various backlight LED current values can be derived analytically. The PWM gate pulses are generated using active current summation technique and it is used to regulate the LED current accurately. The output of QRC is regulated by varying the switching frequency of the converter. The proposed scheme eliminates the series current regulation element present in all conventional LED drivers and it greatly improves efficiency and reduces cost.

Keywords— Discontinuous Conduction Mode (DCM); Quasi Resonant Converter (QRC); Soft Switching, LED Lamp Driver; Zero Current Switching (ZCS); Pulse Width Modulation (PWM)

I. INTRODUCTION

Light Emitting Diode (LED) gradually becomes a commonly used solid-state light source in general lighting applications. It has longer lifetime and has no poison mercury content compared with the conventional fluorescent lamp. Multiple LED lamps are usually connected in parallel for obtaining enough lighting levels. LED driver is essentially a current source or sink which maintains a constant current required for achieving the desired colour and luminous flux from an array of LEDs. LED driver differs from the conventional dc–dc voltage regulator, the quantity is a fixed current rather than a fixed voltage. In solid state, LED drivers regulate the light output by forcing a known current through the LED.

Improvements in solid-state lighting device technology have made Light Emitting Diodes more efficient, compact, low power consuming and long-lasting compared with their halogen tube counterparts. Quasi Resonant Converter based digitally controlled dual-output buck switching LED driver operates in Discontinuous Conduction Mode (DCM) to reduce the input current ripple and extends it to drive multiple outputs. Based on the time multiplexing control scheme in DCM, a theoretical upper limit of the total number of outputs in a buck switching LED driver for various backlight LED current values can be derived analytically. The PWM dimming method is used to dim the LED lamp by modulating its pulse current width. The PWM method of dimming is the actual start and restart of the LED current for short periods of time. A sequential phase-shifted PWM dimming scheme is also used to adjust LED string brightness individually for reducing the input and output current ripple. Every LED string has an individual PWM controller.

Unlike conventional Pulse Width Modulation (PWM) based analog controllers, the proposed digital controller utilizing Quasi Resonant control does not require any compensation circuits because of its inherent stability, hence simplifying the control loop design and reducing the component count and cost.

A. Block Diagram

The block diagram of the proposed system is shown in the Fig. 1. The Quasi Resonant converter is fed from a dc source and it powers multiple LED strings. The PWM controller is used for generating switching sequence. QR Converter operates in Discontinuous Conduction Mode (DCM).

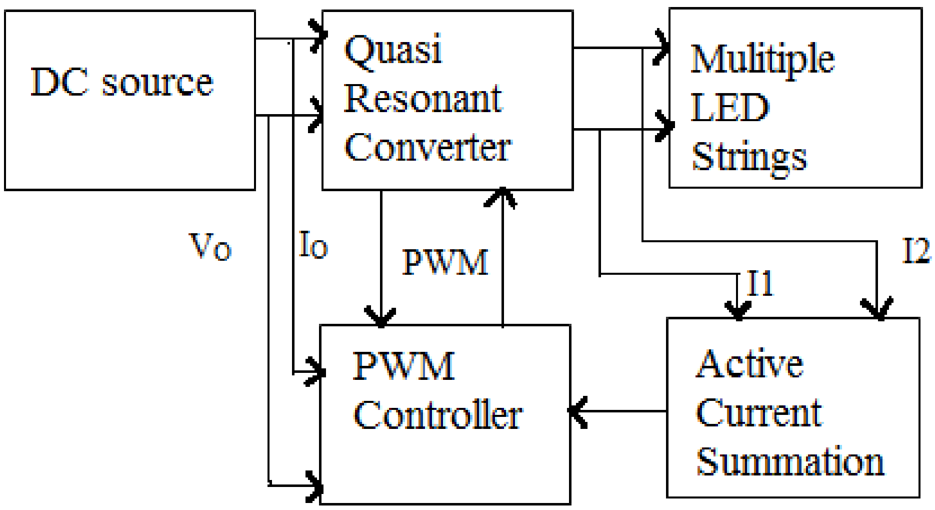

Fig. 1 Block diagram of Proposed System

In this project soft switching based Resonant DC-DC converter has been used for the power conversion, which reduces the switching losses and also increases the overall efficiency of a system.

B. Quasi Resonant Converter

Quasi Resonant Converters (QRCs) can be considered as a hybrid of resonant and PWM converters. The underlying principle is to replace the power switch in PWM converters with the resonant switch. A large family of conventional converter circuits can be transformed into their resonant converter counterparts. The switch current and voltage waveforms are forced to oscillate in a quasi-sinusoidal manner, so that ZCS and ZVS can be achieved. Both ZCS-QRCs and ZVS-QRCs have half-wave and full-wave mode of operations.

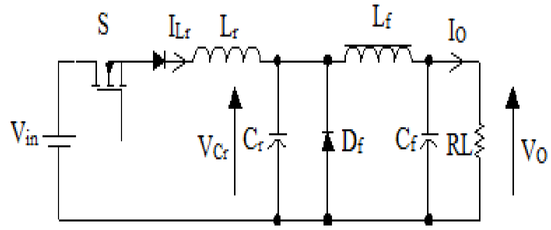

Fig. 2 Schematic diagram of QRC

QRC utilize the principle of inductive or capacitive energy storage and power transfer in a similar fashion as PWM converters. The circuit topologies also resemble those of PWM converters. Fig. 2 shows the schematic diagram of QRC in which the resonant components L_r and C_r have been added around the switch S for the conversion into the Zero Current Switching topology. However an LC tank circuit is always present near the power switch and is used not only to shape the current waveforms through the power switch and the voltage waveform across the device. It can also store and transfer energy from input to output in a manner similar to the conventional Resonant Converters.

II. SIMULATION RESULTS

A. Circuit Diagram Description

The simulink circuit diagram formulated in MATLAB software is shown in the Fig. 3. The input voltage of 10V is given to the block. The inductors and capacitors are used for smoothening the applied dc voltage, to avoid ripples and also for protection. Ig is the gate pulse sequence which is generated by the PWM Block. Generally, by comparing the reference voltage and output voltage (V_o) adequate pulses are generated to maintain proper illumination of LED modules. This comparison of output voltage and reference voltage is done in the comparator.

The powergui block is used to specify either continuous simulation or discretization of the electrical circuit containing diodes. The Error is the mismatch between the output and reference voltage. The outer voltage feedback controller senses the DC voltage and compares it with the reference voltage to generate the error voltage. MOSFET acts as a switch for reducing the switching losses when thyristors are used. The MOSFET is in the on state if the gate-source voltage exceeds the specified threshold voltage. Otherwise the device is in the off state.

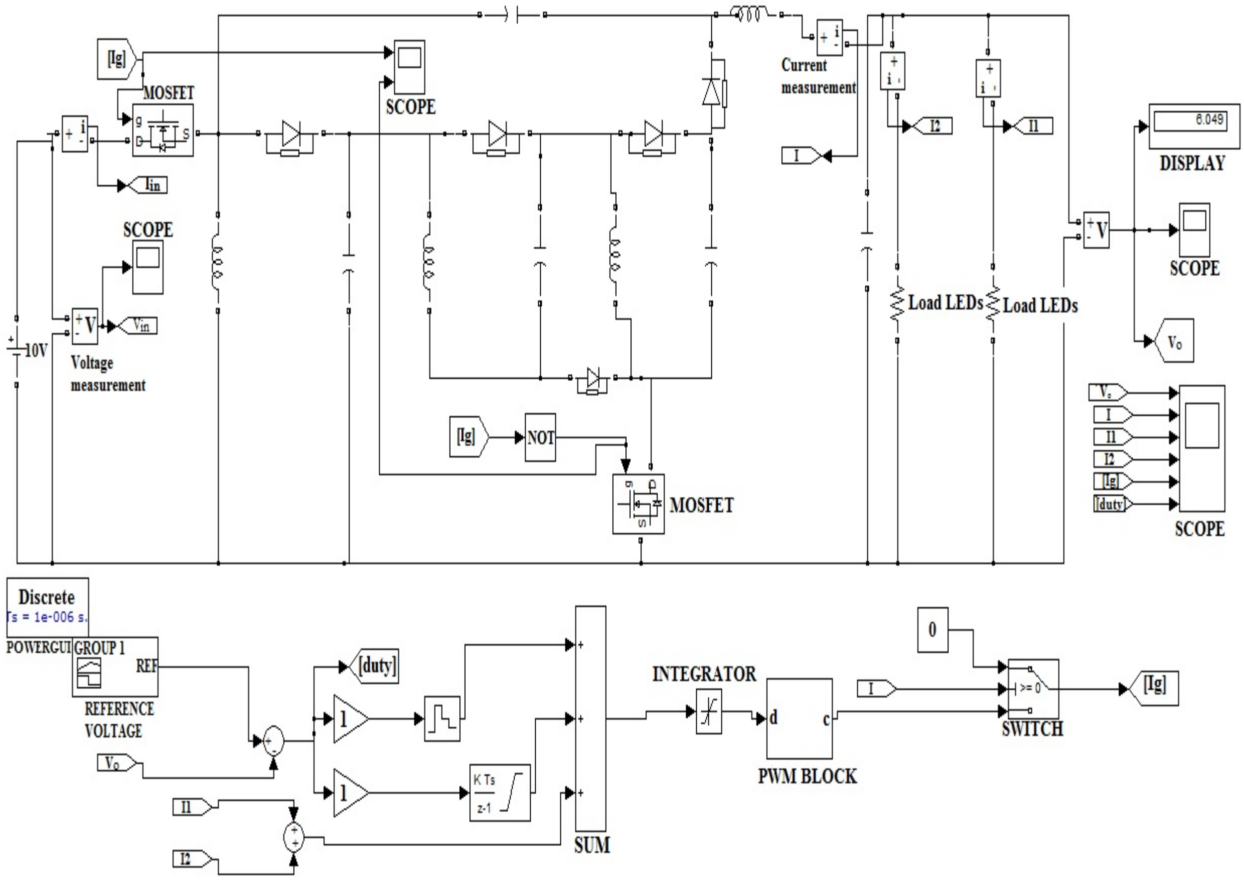

Fig. 3 Simulink circuit diagram

An integral diode in MOSFET protects the semiconductor device by providing a conduction path for reverse current.

- In the on state, the drain-source path behaves like a linear resistor with resistance.
- In the off state, the drain-source path behaves like a linear resistor with low off-state conductance.

The diode is a semiconductor device that is controlled by its own voltage Vak and current Iak. When a diode is forward biased (Vak > 0), it starts to conduct with a small forward voltage Vf across it. It turns off when the current flow into the device becomes 0. When the diode is reverse biased (Vak < 0), it stays in the off state LED driver consists of a diode bridge rectifier and a resistor which provides a constant current to avoid the damage of LEDs.

The following considerations are made to analyze the LED driver.

- All the components of LED driver are considered ideal.
- During steady state LED behaves as a pure resistor.
- DC link voltage must be selected properly to minimize component stress and to confirm DCM operation.

B. PWM Block Circuit

PWM voltage source depends on the reference voltage V_{ref}. The value of the Output voltage amplitude parameter determines amplitude of the output voltage. At time zero, the pulse is initialized as high, unless the Pulse delay time parameter is greater than zero or the demanded duty cycle is zero.

Pulse delay time and Pulse width offset is to add a small turn-on delay and a small turn-off advance. This can be useful when fine-tuning switching times so as to minimize switching losses.

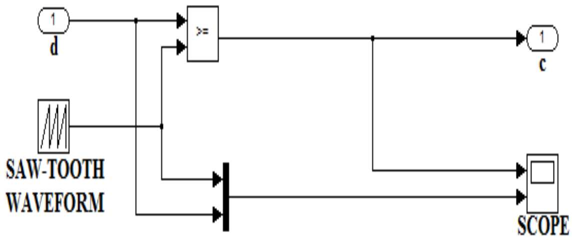

Fig. 4 PWM Block

In Fig. 4 The carrier signal is the saw-tooth waveform which is compared with reference and signals are generated.

C. Input Voltage

The input voltage of fixed 10V DC is applied to the block which is shown in the Fig. 5. The design, modeling and simulation of dual LED strings operating in parallel are carried out in MATLAB/SIMULINK environment for input voltage of 10V with constant load voltage of 6V. It is seen that the supply voltage constant over the whole operation cycle.

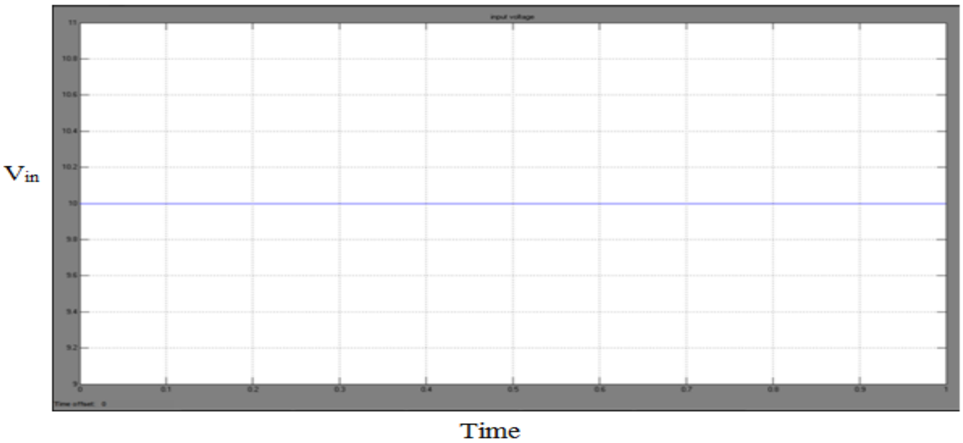

Fig. 5 Input voltage waveform

The inductors are used for reducing the filtering requirements and for minimizing the dc voltage ripples. Thus the harmonics will be less.

D. Pulses

The input pulses from the PWM pulse generator is shown in Fig. 6. The time between updates of the block output state is called the Sample time. The sample time must be a multiple of the simulation step size. In order for the PWM control to have sufficient resolution, set the sample time to less than one hundredth of the PWM period.

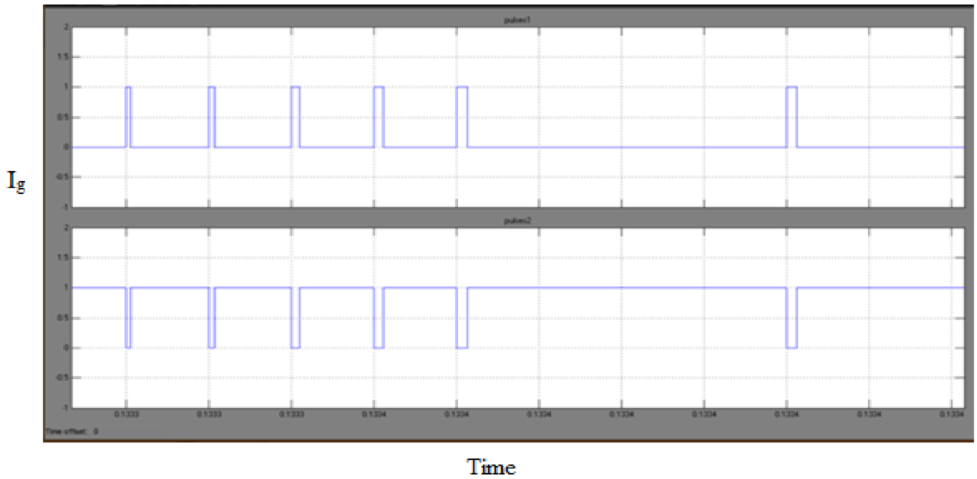

Fig. 6 Gate Pulses

Fig. 6 shows the gate pulses which are used for triggering on the Power semiconductor devices. The sawtooth carrier wave is compared with reference signal in comparator and modulated wave is generated. The width of the pulses are modulated to obtain voltage control and to reduce its harmonic content.

E. Output Voltage

Load LEDs are considered as a resistor at high frequency under the steady state condition. The output voltage obtained from simulimk circuit is shown in the Fig. 7.The voltage increases from 0 and becomes 6V, thus achieving higher scalability of QRC.

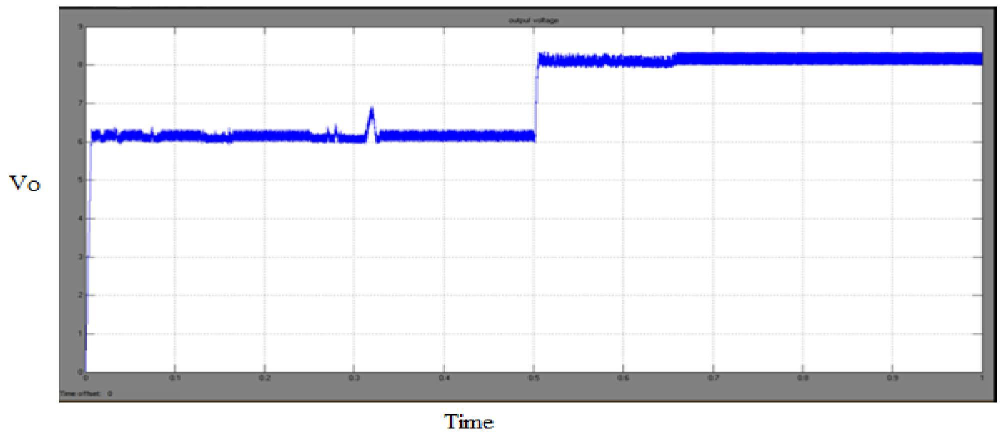

Fig. 7 Output Voltage Waveform

The lamp voltage waveform confirms the constant power operation of the proposed LED drive. The inductor current ensures working in DCM. Hence Quasi Resonant buck converter based LED driver with improved power quality is illustrated in Fig. 7.

III. CONCLUSION

The ZCS-QRC was simulated using MATLAB SIMULINK software. The experimental waveforms of the prototype were shown to verify the feasibility of the proposed scheme. By virtue of this modelling approach, design of Quasi Resonant Converters can be realized efficiently and effectively by using Soft switching techniques. Switching stresses get reduced since voltage and current waveforms have lesser slope. Power density is increased since the volume is reduced. An improved PWM dimming technique is used for regulating the LED current and brightness. The QR digital control scheme does not require loop compensation which simplifies the control loop design and reduces component count. In addition, the proposed architecture offers the advantage of driving a larger number of parallel LED strings without being limited by the maximum current rating of the LED. MOSFET is used as it is a voltage controlled device, the switching time is increased and switching losses are considerably less. It can be concluded that the use Quasi Resonant Converters with appropriate dimming control in multiple LED strings is efficient when large number of LEDs are used in the driver.

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