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LED Driver based on Bridgeless Resonant Pseudo Boost Power Factor Correction Rectifier and Switched Capacitor

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ABSTRACT: This paper proposes LED driver circuit based on bridgeless resonant pseudoboost PFC rectifier and SC. Power supplies with active PFC techniques are becoming necessary for many type of electronic equipment to meet harmonic regulations and standards. A conventional PFC scheme has lower efficiency due to significant losses in diode-bridge. By implementing the pseudoboost topology in the PFC scheme the power factor can be improved to unity by operating in DCM. The bridgeless resonant pseudoboost rectifier is fed to SC converter for LED driver application. The SC converters works for low power applications. The converter is implemented in open loop control. SC converter provides constant current pulse. The SC converter works only with switches and capacitors and energy is transferred by controlling the charging and discharging process.

KEYWORDS: Light Emitting Diode, Power Factor Correction, Discontinuous Conduction Mode, Switched Capacitor, Total Harmonic Distortion.

I.INTRODUCTION

LEDs are the most exciting technological advancement in the lighting industry. The bridgeless resonant pseudoboost rectifier is fed to SC converter to form the proposed LED driver circuit for the application in street lighting. Most of the PFC rectifiers utilize a boost/buck-boost topology converter at their front end due to its high power factor capability. The conventional single-stage PFC ac-dc converters need the full-bridge diode rectifier. The full-bridge diode rectifier increases the conduction losses and decreases the power efficiency. At low line voltage, the full bridge diode rectifier causes high conduction losses, resulting in additional thermal management. These problems can be overcome by eliminating the full-bridge diode rectifier. Compared with other single-phase bridgeless topologies, the bridgeless pseudoboost resonant converter has the merits of less component counts. The absence of an input diode bridge and the presence of only one diode in the current path during each stage of the switching cycle result in higher power density and less conduction losses. Thus improved thermal management compared to existing PFC rectifiers is obtained. The pseudoboost resonant converter topology is designed to work in resonant mode to achieve an automatic PFC close to unity in a simple and effective manner. The pseudoboost converter is designed to operate in DCM during the switch turn on intervals and in resonant mode during the switch turn off intervals. The voltage transfer ratio of the pseudo boost resonant converter is similar to that of conventional boost converter.

The SC converter is a half bridge converter which works for low power applications. During one switching period, switched capacitor in the SC converter is charged and discharged. The energy stored in the capacitor is transferred to the load. Switched capacitors have light weight, small size and high power density. It uses a small inductor to improve the switching behaviour and it does not affect the power transfer to the relay. The converter operates in DCM. The control of the LED current is performed by the SC, which is a prominent advantage of the circuit. The SC responsible for limiting the power transferred to the LEDs. Thus, the average output current is directly proportional to the switching frequency, considering that the input voltage is constant. Therefore, closed loop operation is not necessary to regulate the LED current. The converter is implemented in open loop control. This LED driver has the advantages of both bridgeless and transformer-less topology, thus an increased efficiency is obtained. Another advantages includes single control signal, less conduction loss, reduce turn on switching loss, high power density and lower cost. Thus improves the performance of the system.

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II.LITERATURE REVIEW

The conventional LED driver is a two stage system is constructed by a constant current control DC/DC converter with a PFC stage. A new control method of interleaved single stage fly back converter for outdoor light emitting system is is proposed. These solutions need more components and require two driver circuits. A novel single stage high power factor LED driver with coupled inductors integrates a dual buck boost PFC converter with coupled inductors and a half bridge type LLC resonant converter into a single stage circuit topology. This converter features cost effectiveness and low input current THD. In a high PF single stage single switch electronic ballast for compact fluorescent lamps the proposed circuit is designed by integrating a SEPIC PFC with a novel single switch current fed resonant inverter. The advantage is that it simplifies the gate drive circuit. The overall efficiency of the circuit is 82%. In the paper a single stage single switch HPF electronic ballast for fluorescent lamps the topology originates from the integration of a buck boost PFC converter and class E electronic ballast. Here only one active switch is commonly used by both power stages to save the cost of active switches and control circuit. The high PF for the PFC stage will resort to an excessively high dc link voltage. In a novel single stage high PF ac/dc LED driving circuit with leakage inductance energy recycling a buck boost PFC is integrated with a fly back converter. A recycling path is build to recover the inductive leakage energy. In this way, the presented circuit provide low THD, high conversion efficiency and low switching voltage spikes. But the switching loss of the circuit is high. With the recycling path the LED driver circuit achieves efficiency of 90%. In the paper analysis and design of the IDBB converter as a high PF driver for power LED lamp, an IDBB converter is proposed as a high PF offline power supply for power LED lamps. The IDBB converter features just one controlled switch and two inductors and is able to supply a solid state lamp from the mains. The efficiency of the system is 87.5%.

III.CIRCUIT DESCRIPTION

The proposed LED driver circuit is based on a bridgeless resonant pseudoboost rectifier and a switched capacitor. The bridgeless resonant pseudoboost rectifier is for the power factor correction. Switched capacitor is used to drive the LED. Fig 1 shows the proposed LED diver circuit. It consists of an ac voltage source, input filter circuit, bridgeless resonant pseudoboost PFC rectifier and switched capacitor. Output of bridgeless resonant pseudoboost PFC rectifier is fed to SC converter. LED is the load.

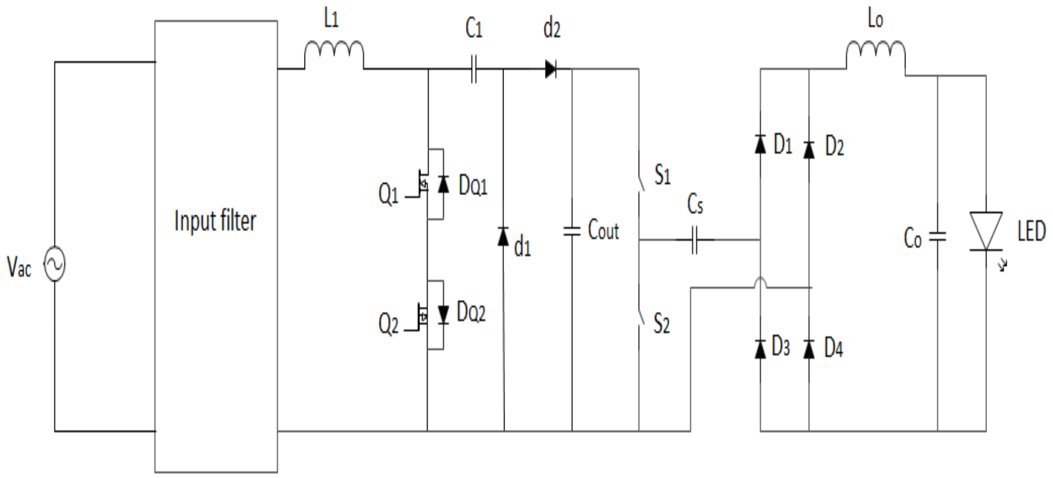

Fig. 1 Proposed LED driver based on bridgeless resonant pseudoboost PFC rectifier and switched capacitor

IV.CIRCUIT OPERATION

Bridgeless resonant pseudoboost PFC rectifier is as shown in the figure 2. Circuit operation can be divided into four operating stages during one switching period. The stages of rectifier over a switching cycle can be briefly described as follows.

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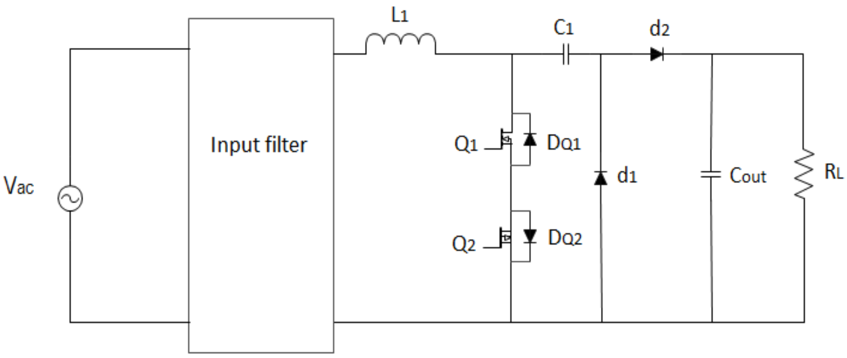

Fig. 2 Circuit configuration of bridgeless resonant pseudoboost PFC rectifier

A) Stage 1

This stage starts when the switch Q_1 is turn on. The body diode of Q_2 is forward biased by the inductor current $i_{L1.}$ Diode D_1 is reverse biased by the voltage across C_1, while D_2 is reverse biased by the voltages $V_{C1}+V_0$. In this stage, the current through inductor L_1 increases linearly with the input voltage, while the voltage across capacitor C_1 remains constant at voltage V_X.

B) Stage 2

This stage starts when switch Q_1 is turned off and diode D_2 is turned on simultaneously providing a path for the inductor current i_L1. As a result, diode D_1 remains reverse biased during this interval. L_1 and C_1 are excited by the input voltage V_{ac} through diode D_2. This stage ends when the resonant current i_{L1} reaches zero and diode D_2 turns off with zero current. During this stage, capacitor C_1 is charged until it reaches a peak value.

C) Stage 3

During this stage diode D_1 is forward biased to provide a path during the negative cycle of the resonating inductor current i_{L1}. This stage ends when the inductor current reaches zero. Thus, during this stage diode D_1 is switched on and off under zero current conditions. Assuming the constant input voltage over a switching period, the capacitor is discharged until it reaches a voltage V_X

D) Stage 4

During this stage all switches are in their off state. The inductor current is zero, while the capacitor voltage remains constant. The resonant mode achieves an automatic PFC close to unity in a simple and effective manner.

The switched capacitor converter is as shown in the figure 3. The operation of SC converter consists of six stages. The stages can be described as follows.

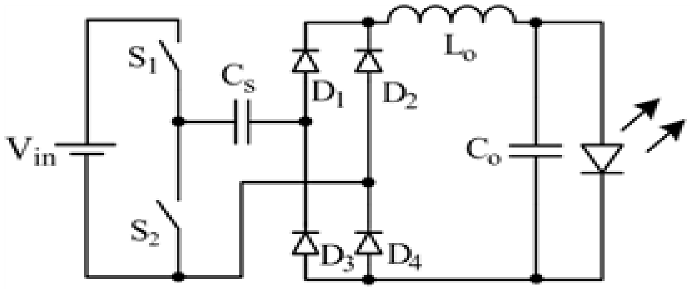

Fig. 3 Circuit configuration of switched capacitor

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A) Stage 1

At instant t_0, the voltage across C_s capacitor is null. Besides, switch S_2 is turned off and switch S_1 is turned on. The voltage across C_s increases until it reaches the input voltage V_{in}. At instant $t = t_2$, the current through capacitor C_s becomes zero. At t_1, the peak current flows through capacitor C_s.

B) Stage 2

During this stage, the remaining energy stored in L_o flows through the diodes and such current decreases linearly to zero at $t = t_3$. Since the diodes are considered as ideal, all four diodes remains tuned on.

C) Stage 3

During this stage, capacitor C_o provides energy to the LED. At $t = t_3$, half the energy provided by the input source is transferred to the load represented by the LED and C_o. Within the same time, the remaining half is stored in the switched capacitor C_s. This stage is similar to the second one an

D) Stage 4

At t_4, the voltage across C_s is equal to V_{in}. Besides, switch S_1 is turned off and switch S_2 is turned on. During the time interval corresponding to this stage, the whole energy stored in capacitor C_s is transferred to the load. At $t = t_5$, the peak current flows through capacitor C_s. At $t = t_6$, the voltage across C_s is null.

E) Stage 5

This stage is similar to the second one and the same conditions are valid in this case. During this stage, the remaining energy stored in L_0 flows through the diodes and the current decreases linearly to zero.

F) Stage 6

This stage is similar to the third one. Here the conditions of the third stage are valid in this case. During this stage capacitor C_0 provides energy to the LED.

V.SIMULATION

The simulation work was done in MATLAB - SIMULINK. The simulink model of the proposed system is given in the figure 4. The circuit is designed for a switching frequency of bridgeless resonant pseudoboost rectifier as 50 KHz and switching frequency of switched capacitor as 13 KHz. The output voltage is taken as 15V and input voltage is 13V. Open loop control is used in the proposed LED driver circuit.

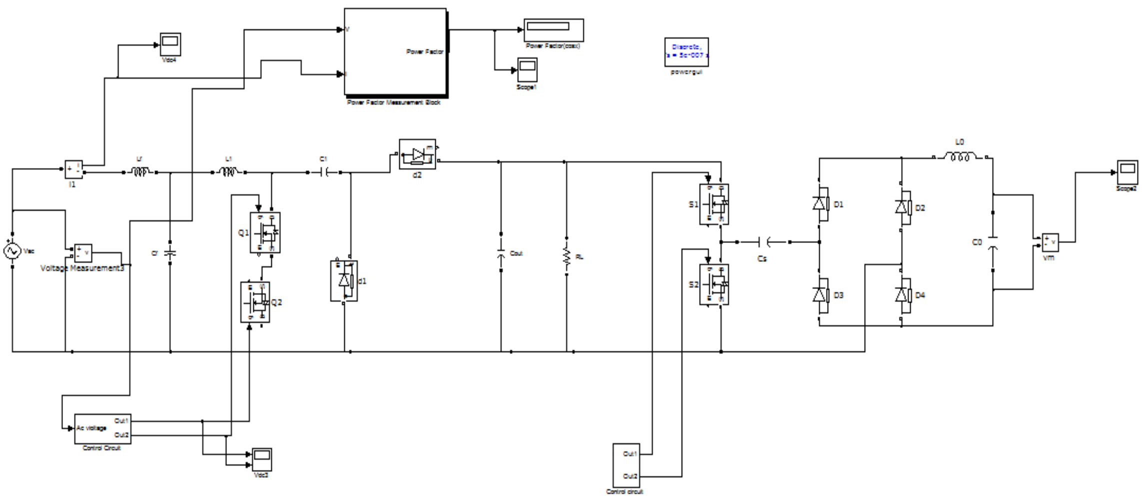

Fig. 4 Simulink model of the LED driver based on bridgeless resonant pseudoboost rectifier and switched capacitor

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The gate pulses generated for the bridgeless resonant pseudoboost PFC rectifier by using the open loop control is given in the figure 5. The gate pulses generated for the switched capacitor by using the open loop control circuit is shown in the figure 6. The gate pulses generated for the switches Q1 and Q2 in bridgeless resonant pseudoboost PFC rectifier is complimentary. Similarly the gate pulses generated for the switches S1 and S2 in switched capacitor is complementary nature. The two power switches Q1 and Q2 n be driven by the same control signal. The switches S1 and S2 in the switched capacitor can be driven by the same control signal. This significantly simplifies the control circuitry of the proposed LED driver.

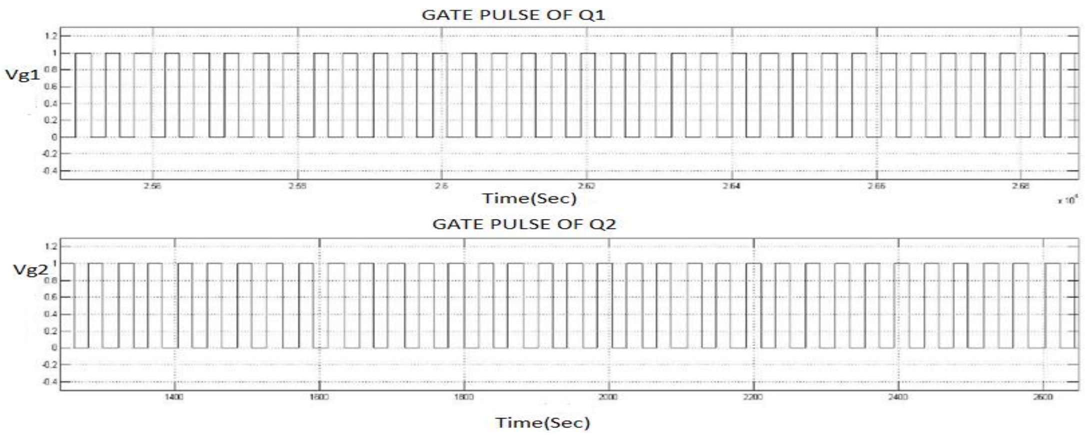

Fig. 5 Gate pulses for bridgeless resonant pseudoboost PFC rectifier

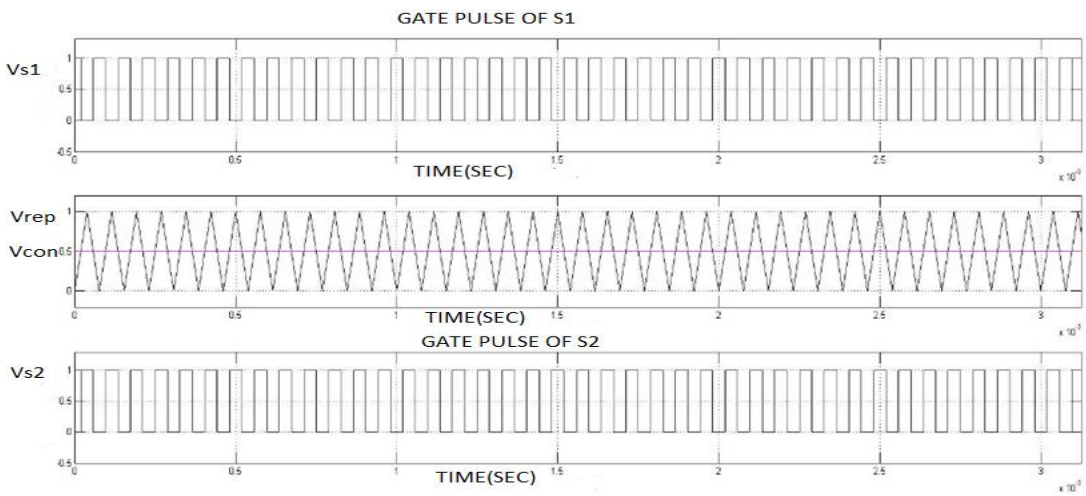

Fig. 6 Gate pulses for switched capacitor

The output voltage waveform of the proposed LED driver circuit based on bridgeless resonant pseudoboost rectifier and switched capacitor is shown in the figure 7. The LED driver circuit is designed for an output voltage of 15V. The simulink model gives an output voltage 14.3V.

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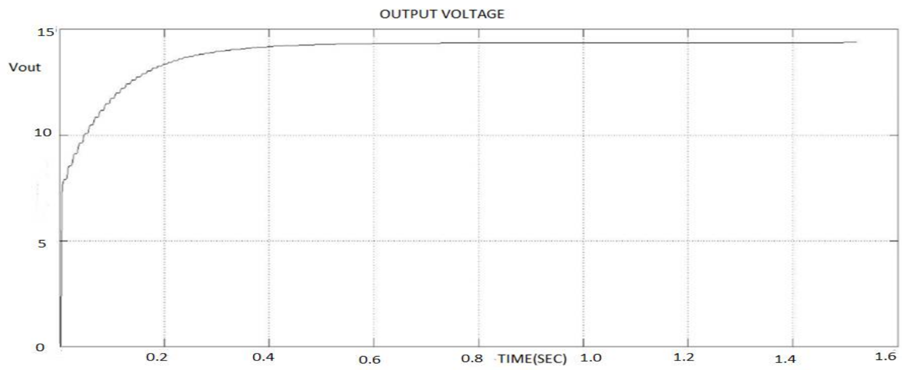

Fig. 7 Output of LED driver based on bridgeless resonant pseudoboost rectifier and switched capacitor

The THD waveform is shown in the figure 8. The proposed LED driver circuit gives THD of 10.39%.

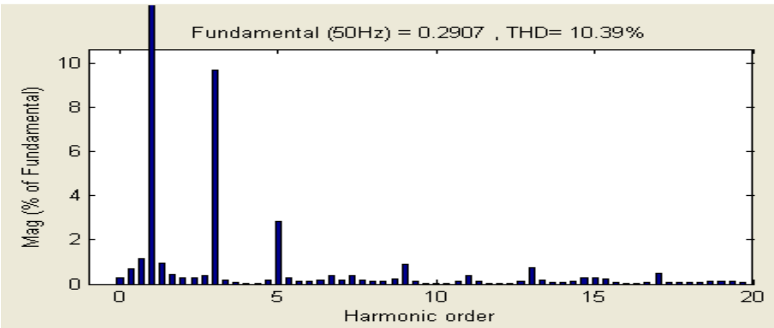

Fig. 8 THD of proposed LED driver circuit

The PF of the proposed LED driver circuit is shown in the figure 9. The proposed LED driver gives a PF of 0.993. PF is measured by using the equation,

PF= cos φ = VI cos φ/ VI

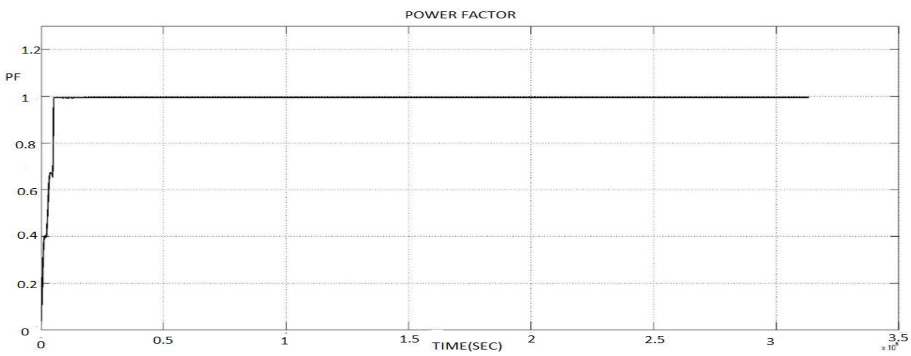

Fig. 9 PF of proposed circuit

VI .HARDWARE IMPLEMENTATION

The hardware implementation of the proposed LED driver is shown in the figure 10. Here front end PF correction is possible by the pseudoboost converter which is followed by an SC converter for LED driver application. High efficiency MOSFET used as switch. To perform the various operations and conversions required to switch, control and

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monitor the devices ATmega 16 chosen. For the efficient operation of the controller circuit, a driver circuit and synchronizer circuits are added. Output voltages obtained are shown in the figure 11 and figure 12.

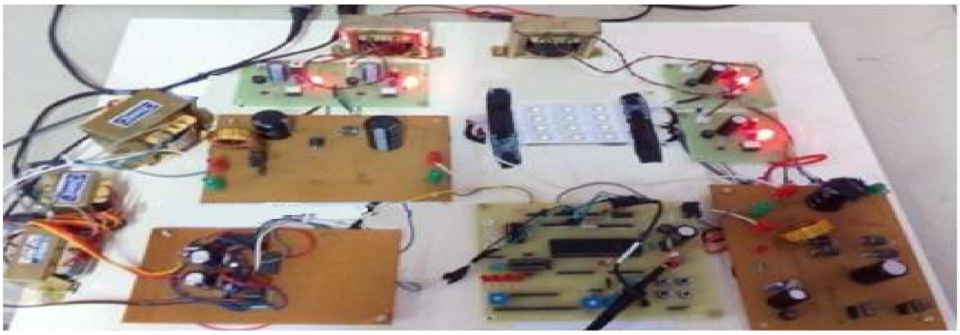

Fig. 10 Hardware of proposed LED driver circuit

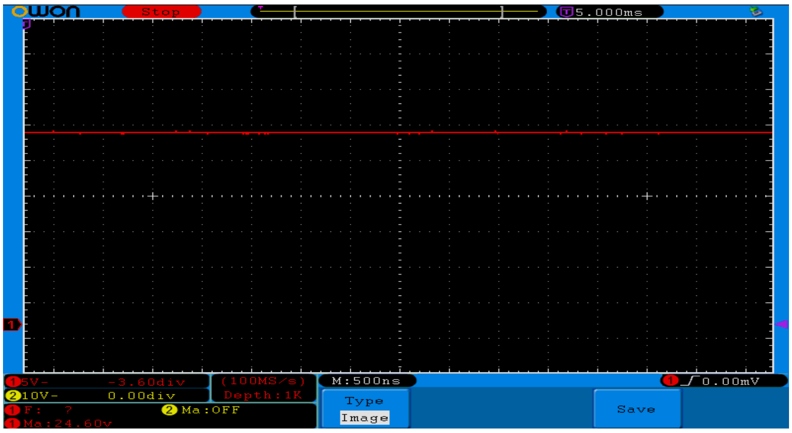

Fig. 11 Output voltage of bridgeless resonant pseudoboost PFC rectifier

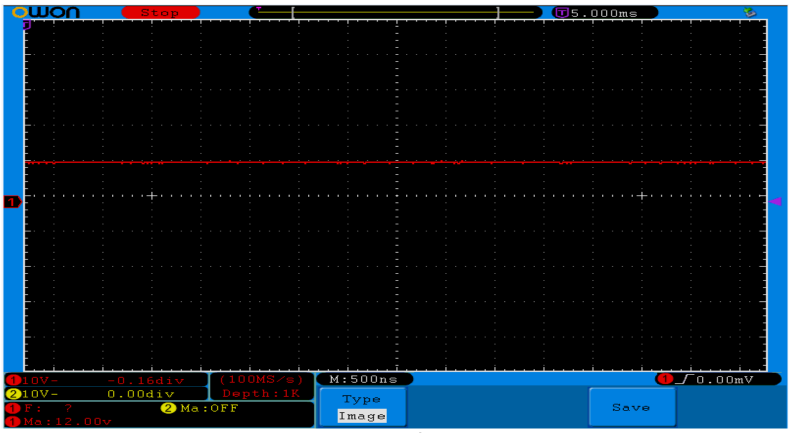

Fig.12 Output voltage of switched capacitor

Output voltage of resonant pseudoboost PFC rectifier obtained is 24.6V. Output voltage of switched capacitor obtained is 12V.

VII .RESULT

Simulation of circuit is carried out in MATLAB – SIMULINK for analysing the performance of proposed LED driver circuit. The circuit is designed for an output voltage of 15V. The simulink model of proposed LED driver gives output

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voltage of 14.3V. PF obtained is 0.993 and the circuit gives THD of 10.39%. The hardware implementation gives an output voltage of 24.60 for the bridgeless resonant pseudoboost PFC rectifier and 12V for SC converter. The proposed circuit provides high power factor and low THD. The circuit use single control signal.

VIII .CONCLUSION

The proposed LED driver is based on based on bridgeless resonant pseudoboost rectifier and switched capacitor. This LED driver has the advantages of bridgeless and transformer-less topology, thus an increased efficiency is obtained. Compared with existing single phase bridgeless topologies, the new pseudoboost topology has low component count and a single control signal. The bridgeless resonant pseudoboost rectifier is designed to operate in DCM during the switch turn on interval and in resonant mode during the switch turn off intervals. Thus achieves automatic PFC. The bridgeless resonant pseudoboost rectifier is fed to SC converter for LED driver application. The SC converter operates with high efficiency, high frequency and negligible losses. The SC has the advantages of lower cost, small size and light weight. The proposed circuit provides high efficiency and better performance.

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