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MODELING AND REALIZATION OF SINGLE SWITCH BRIDGELESS SEPIC CONVERTER

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Abstract

The single-ended primary-inductor converter (SEPIC) is capable of operating from an input voltage that is greater than the regulated output voltage. Aside from being able to function as both a buck and boost converter, the SEPIC also has minimal active components, a simple controller, and clamped switching waveforms that provide low noise operation. In this work, a bridgeless single switch topology of SEPIC converter is designed initially. The simulation of the designed converter is obtained using MATLAB and hardware setup for bridgeless SEPIC converter is also carried out in this paper. In future a modified topology for the existing topology is obtained by using the RC damping to the existing circuit. Also various controllers would be applied to this system and the transient and steady state response would be studied in the next phase.

Keywords-- *single-ended primary-inductor converter (SEPIC), converter topology, Modelling.*

I. INTRODUCTION

Step up/down converters exhibit a number of interesting properties that make them attractive for different applications. The key feature of these converters is the ability to operate with a wide range of input voltages, which can be lower or higher with respect to the output voltage. Low voltage battery powered devices such as PDAs make use of the flexibility of these converters to fully exploit Li-Ion batteries. Automotive applications need a power conversion stage that is able to supply different loads with a regulated voltage while withstanding severe line transients due to battery voltage fluctuations. As an example, typical requirements for an automotive stereo system power supply are an input voltage varying in the range 10V−40V and a regulated output voltage of 15V. Stand-alone PV systems also benefit from the use of step up/down converters.

The simplest step up /down power converters are the buck-boost and the fly back. Low components count, well understood dynamics properties and easy implementation using commercially available ICs are the main advantages of these converters.However, both converters also suffer from some drawbacks. The most obvious limitation is that both the input and the output capacitors have to sustain a high frequency pulsating current. In both converters, the input voltage source is periodically disconnected, as in a buck converter. This requires the addition of bulky input capacitors (usually electrolytic) and possibly the use of an input inductance to reduce the harmonic content injected towards the source. The output load is also periodically disconnected from the power supply, as in a boost converter.

For low and medium power applications, a complete AC/DC power supply with PFC can be realized using the SEPIC. The SEPIC (Single Ended Primary Inductance Converter) is gaining widespread acceptance in the literature and in the market. Both converters are characterized by the presence of an input inductance, which reduces the RMS content of the input capacitor current. For a given application, the use of SEPIC converters instead of a fly back converter may allow the reduction of the size and capacitance of the input

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capacitors. Hence, although both SEPIC converters make use of an additional inductor and of an additional capacitor if compared with fly back or buck-boost, the reduced size of input and output filters may allow obtaining comparable power densities.

II. LITERATURE REVIEW

For the converter, SEPIC topology can be used when an output voltage independent of the maximum input voltage is required. Several topologies are available for the SEPIC converters. Many literatures deal with those topologies, their operating modes, merits and demerits and their applications. In this paper [1], a new bridgeless single-phase AC-DC converter with an automatic power factor correction (PFC) is proposed. The proposed rectifier is based on the single-ended primary inductance converter (SEPIC) topology and it utilizes a bidirectional switch and two fast diodes. The absence of an input diode bridge and the presence of only one diode in the flowing-current path during each switching cycle result in less conduction loss and improved thermal management compared to existing PFC rectifiers.

Other advantages include simple control circuitry, reduced switch voltage stress, and low electromagnetic-interference noise. Performance comparison between the proposed and the conventional SEPIC PFC rectifier is performed. Simulation and experimental results are presented to demonstrate the feasibility of the proposed technique. In this study [2],An average model of SEPIC converters with coupled inductors was developed and verified against cycle-by-cycle simulations. The model can be used as is by any modern circuit simulator to run steady state (DC), large signal (transient) and small signal (AC) analyses. The inductors coupling coefficient, incorporated as a parameter in the model, can be varied from zero to almost unity. Zero coupling coefficients represent the case of a SEPIC converter with uncoupled inductors.In this paper [3], an interleaved SEPIC converter with LED current dimmable and input power factor correction is proposed as a high performance driver for the high brightness white LEDs. The converter is controlled with voltage mode PWM and run in discontinuous conduction mode so that the inductor current follows the rectified input voltage. The critical design constraints and equations for both the power stage and control loop are highlighted and detailed. The proposed converter can be used to drive a wide number of high brightness LEDs for industrial or commercial lighting applications.

This paper discusses the design of the SEPIC converter, design of the coupled inductor to achieve ripple current steering, and Zero Voltage Transition circuitry to minimize switching losses [4]. The SEPIC is often identified by its use of two magnetic windings. These windings can be wound on a common core, as in the case of a coupled dual-winding inductor, or they can be the separate windings of two uncoupled inductors. Designers are often unsure of which approach is best and whether there is any real difference between the two [5]. This article looks at each approach and discusses the impact each has on a practical SEPIC design. This application note presents the basic equation of the SEPIC converter in addition to design guidelines for a SEPIC PFC operating in transition mode and using the ripple steering technique [6]. An application example with some tests results and waveforms is also provided in the document.

III. SEPIC PFC Converter

A SEPIC converter is a less popular topology for PFC converter design because the control can be complex, due to its 2 pairs of un-damped complex poles, compared with other PFC converters, such as the boost converter, fly-back converter. The advantage of the SEPIC converter is that its output voltage is not necessarily limited by its input voltage range. This property means that the output voltage can be higher or lower than input voltage. Moreover, this property means that the SEPIC PFC converter does not require an additional dc/dc stage for LED applications. Additionally, the SEPIC converter can reduce the input current ripple by incorporating two properly wound inductors. This characteristic means that the power loss due to the current ripple can be reduced. Figure 1, shows the circuit diagram of the SEPIC converter.

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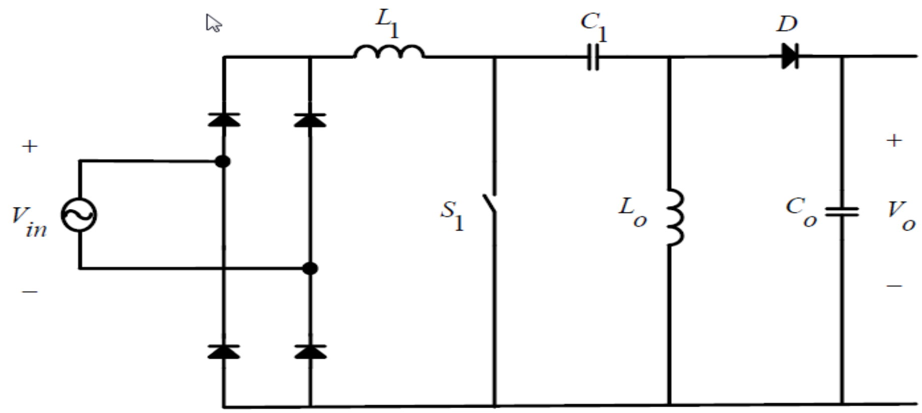

Figure 1: SEPIC PFC Converter

Operation Mode Analysis

- ***Switch-On stage***

Figure 2.shows the on-time diagram for switch S_1, for which switch S_1 is on, and diode D_1 is off. The input side inductor L_1 is charged from the input voltage in this stage, the charged C_1 transfers energy into the output side inductor Lo, and Lo is charging in this stage. In addition, the load current comes from the charged output capacitor Co. Based on the inductor volt-second balance and the capacitor charge balances; (Equations 1 to 4) is obtained.

- The voltage across L_1 is the same as input voltage, V_{in}.

$$L_1 \frac{di_{L_1}}{dt} = v_{in} \qquad (1)$$

- The voltage across Lo is the same as the voltage across capacitor, C_1.

$$L_o \frac{di_{L_o}}{dt} = v_{C_1} \qquad (2)$$

- The current through C_1 is the same as the current through inductor L_2.

$$C_1 \frac{dv_{C_1}}{dt} = -i_{L_o} \qquad (3)$$

- The current through C_o is the same as the load current.

$$C_o \frac{dv_{C_o}}{dt} = -\frac{v_{C_o}}{R} \qquad (4)$$

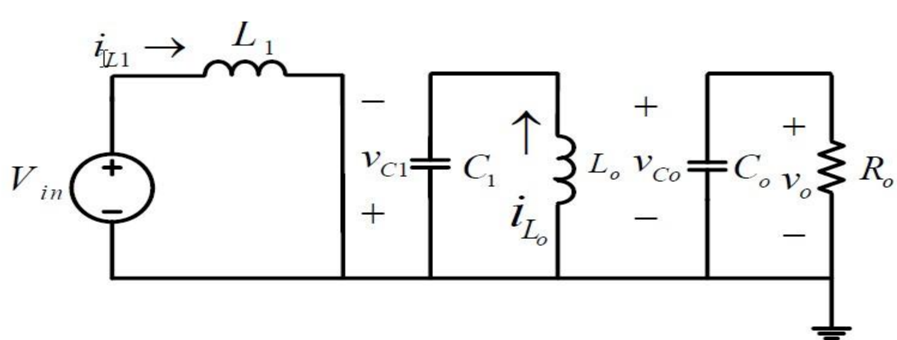

Figure 2:Operation of the SEPIC Converter Switch on- Stage.

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- ***Switch-Off stage***

Figure 3 shows the off-state diagram for switch S_1, in which switch S_1 is off and the diode D_1 is on. Inductor L_1 charges the capacitor C_1 and provides the load current. The Inductor L_2 is connected to the load. It charges the output capacitor Co and provides the load current. (Equations 5 to 8) are obtained according to the volt-sec balance and the capacitor charge balance.

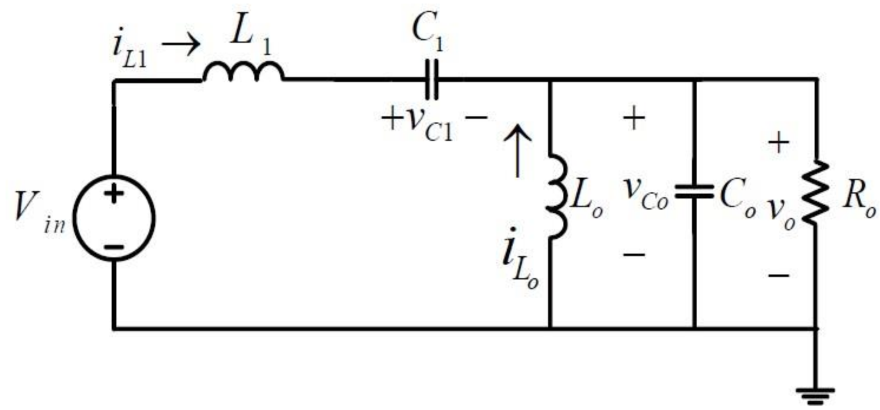

Figure 3 Operation of the SEPIC Converter Switch Off-Stage

- The voltage across L_1 is the same as the input voltage, V_{in}.

$L_1 \frac{di_{L_1}}{dt} = v_{in} - v_{C_1} - v_{C_o}$ (5)

- The voltage across Lo is the same as the voltage across capacitor C_1

$L_o \frac{di_{L_o}}{dt} = -v_{C_0}$ (6)

- The current through C_1 is same as the current through inductor L_1

$C_1 \frac{dv_{c_1}}{dt} = i_{L_1}$ (7)

- The current through Co is the sum of currents through two inductors and the current of the load substrate

$C_o \frac{dv_{c_o}}{dt} = i_{L_1} + i_{L_o} - \frac{v_{C_o}}{R}$ (8)

IV. BRIDGELESS SEPIC PFC CONVERTERS

Bridgeless PFC topologies are currently gaining increasing interests. Generally, bridgeless PFC converters suffer from the difficulty of implementation and control, but a bridgeless topology can reduce conduction losses from rectifying bridges; thus, overall system efficiency can be increased. In addition, a bridgeless topology has the advantage of total harmonic distortion (THD) decreasing from input diode reduction. The bridgeless converter circuit shown in Figure 1.2 is typically popular for bridgeless topologies, in which the converter operates separately over positive and negative cycles. This circuit is simple and easy to implement, there are fewer limitations to choosing the main passive components. This circuit can be modified into a single-switch bridgeless converter, which has low conduction loss and requires fewer components.

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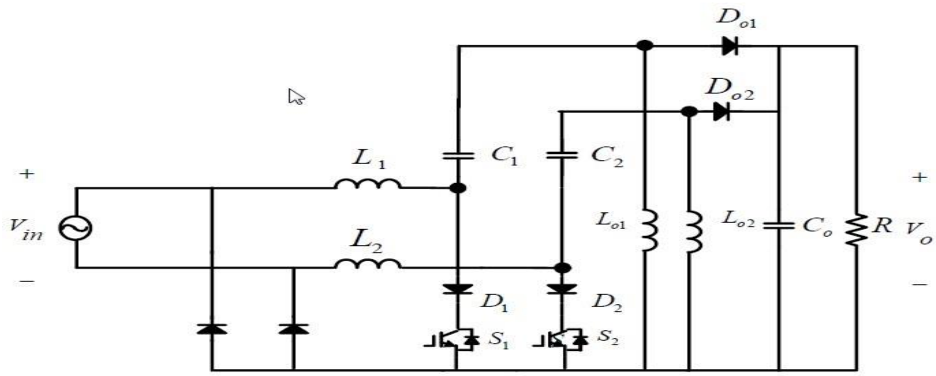

Figure 4: Bridgeless SEPIC PFC Converter

Figure 4, shows a bridgeless SEPIC converter that has 2 switches. This circuit requires MOSFET Q1 and Q2 and a series of high-voltage ultra-fast diodes. Thus, the switching and conduction losses are increased. Figure 5, shows a single-switch SEPIC converter, which reduces switching and conduction losses but may result in high circulating current losses due to the undesired capacitive coupling loop.

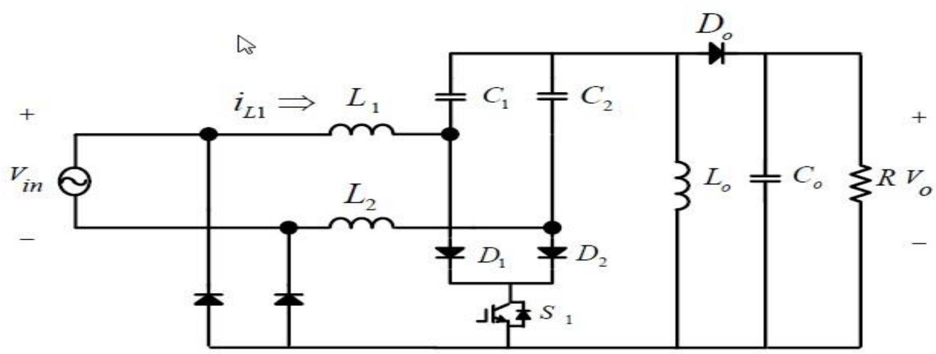

Figure 5:Single Switch Bridgeless SEPIC PFC Converter

Operating Modes

Mode: 1

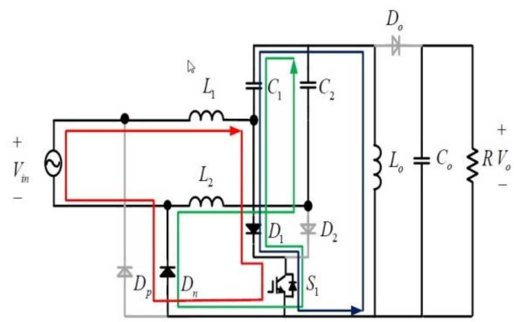

Figure 6: Diagram of the bridgeless SEPIC PFC converter (switch-on).

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Mode:2

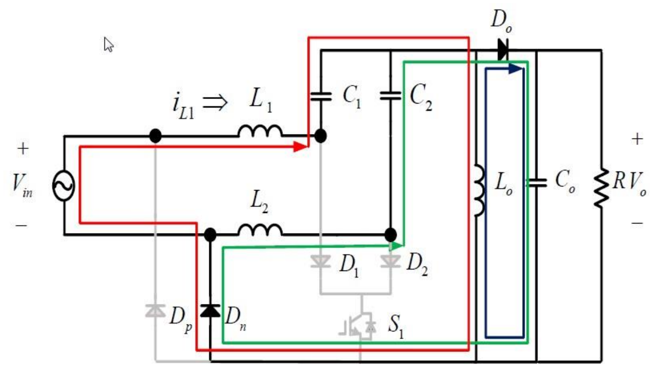

Figure 7: Diagram of the bridgeless SEPIC PFC converter (switch-off).

IV. SIMULATION

The simulation of bridgeless SEPIC converter is done using MATLAB. Using MATLAB the required components(blocks) such as diode, inductor, pulse generator, MOSFET, resistor and capacitor are selected. The simulation diagram is shown in figure 8.

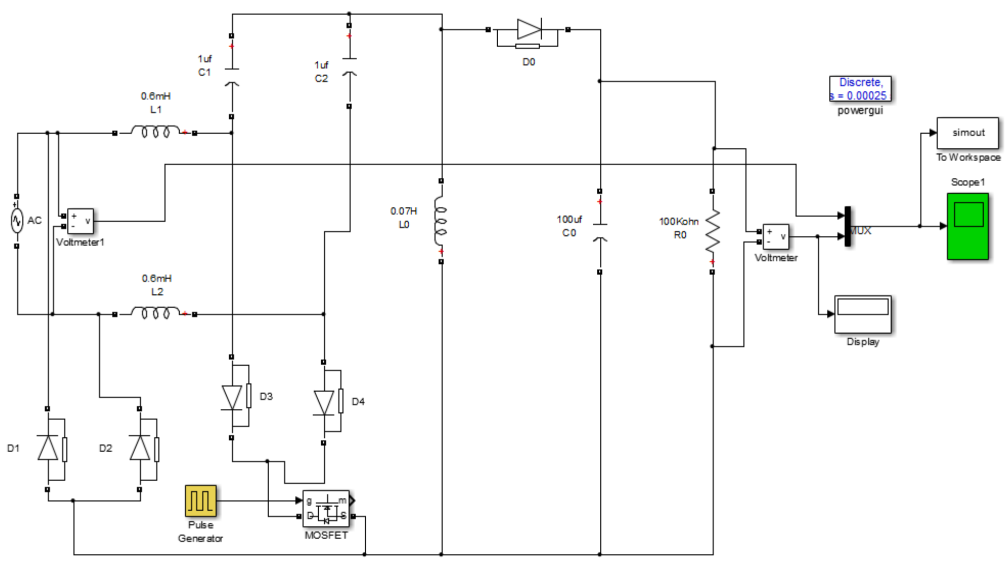

Figure 8:Simulation of Single switch bridgeless SEPIC converter.

OUTPUT WAVEFORM OF BRIDGELESS SEPIC CONVERTER

Input voltage applied to the SEPIC converter is 12Volt(AC) and the output voltage obtained from SEPIC converter is 54Volt(DC). These input and output waveforms are shown in the figure 9. The figure 9clearly providesinformation (boosting character) of the SEPIC converter.

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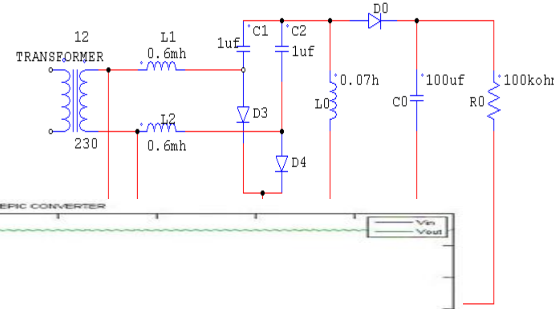

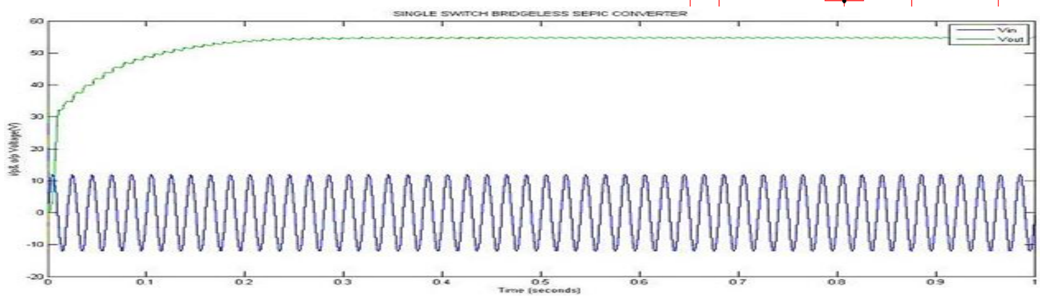

Figure 9: Output Waveform of Single Switch Bridgeless SEPIC Converter

VI. HARDWARE DESIGN

a. Power Stage Specification

The power stage specifications of the bridgeless SEPIC PFC converter, as shown in Figure 5.1, are designed as follows:

- Input voltage (V_{in}) :230 ~12 RMS V at 50 Hz
- Output voltage (V_0) : 50 V
- Output power (P_0) : 150 W
- Switching frequency (F_s) : 1K Hz

b. Components Selections

The main components were selected according to the following rationale:

- Energy transfer capacitors C_1&C_2: 1uF
- Output capacitor C_0: 100uF
- Input inductors L_1&L_2:0.6mh
- output inductor L_0: 0.07H
- Load resistance R0:100kohm

c. Circuit Diagram

This circuit diagram of single switch bridgeless SEPIC converter was shown in figure 10. The mode of operations of this SEPIC converter is already explained in the previous chapter. The input of 230V is applied to the transformer which steps down the voltage to 12V. The SEPIC converter designed boosts the 12V input to around 59.8Volts when practically tested. This SEPIC converter works based on the chosen circuit component values and switching frequency of the control circuit.

d. Experimental Setup

The single switch bridgeless SEPIC converter is designed by experimental setup. This setup is carried out by using control circuit and power circuit from figure11.

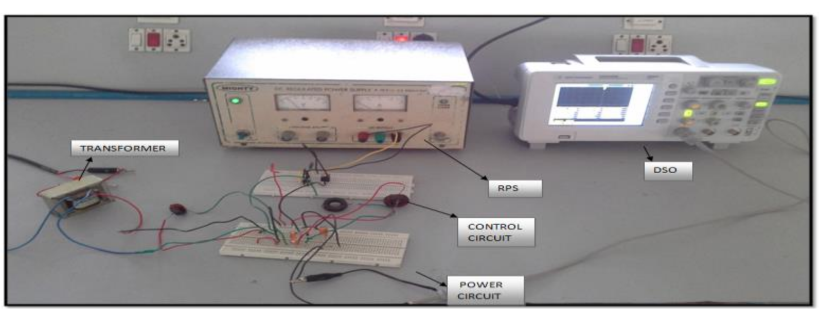

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Figure 11:Experimental setup of single switch bridgeless SEPIC converter

e. Output Waveform of Control Circuit

This control circuit of TIMER555, the output waveform which has obtained voltage maximum Vmax is 5.52V then, the voltage average Vavg is 3.8V and the frequency is practically we got 1KHZ and it get experimentally as 962HZ is generated in control circuit from figure 12.

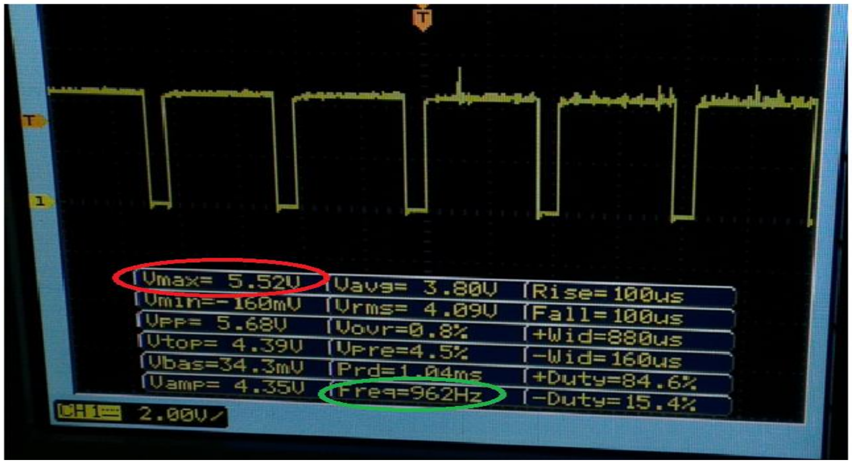

Figure 12: Output Waveform of Control Circuit

f. Output Voltage Waveform of Power Circuit

This power circuit of single switch bridgeless SEPIC converter output waveform which has obtained the voltage experimentally we got 59.8V is generated in this output waveform. In simulation the output voltage is get as 54V is obtained from figure 13.

Figure 13: Output voltage waveform of power circuit

g. Comparisons

Table 1: between Simulation Result and Experimental Work

COMPARISONS	INPUT	OUTPUT
Simulation using MATLAB	12V	54V

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Experimental	12V	59.8V

VII. CONCLUSION

Simulation of single switch bridgeless SEPIC converter is performed and the experimental setup of single switch bridgeless SEPIC converter also performed. The output voltage waveforms of both the simulation and experimentally were analyzed. In simulation we get the output voltage of 54V will perform and the experimentally we got the output voltage of 59.8V will perform this single switch bridgeless SEPIC converter.

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