Hardware Implementation of Non-isolated Sextuple Output Hybrid Converter

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Abstract: *A new derivative of DC-DC converter without isolation with the help of conventional dc-dc converters fit for renewable energy and high-voltage applications. Integration of switched inductor circuit in power circuit lifts the voltage. And so, it overpowers the parasitic effects of the circuit components. Conventional DC-DC converters like SEPIC, Cuk, Zeta, Boost, etc., are employed for renewable energy and industrial applications. However they suffer from parasitic effects with reduced output voltage, and limited with low efficiency. These problems are overruled by the non-isolated DC-DC output converter for augmenting the output voltage. This converter is having single semiconductor switch without any isolation and able to supply high output with varying duty cycle. A simulation of converter capable of sextuple DC outputs from single DC input with varying duty ratio is presented. Additionally, an experimental prototype with six different output voltages based on a Single-Ended Primary Inductance (SEPIC)-Cuk-Zeta combination is developed.*

Keywords: *Sextuple output-Non-isolated-Single semiconductor switch-SEPIC-Cuk-Zeta*

I. INTRODUCTION

Due to upsurge of electronic and electrical devices for facilitation of human being, there is also increase in electricity consumption. Though, the source of electricity is a very worthless reserve it is exhausting for every single seconds of the lifecycle. That's why; electrical devices should critically ensure maximum level of power efficiencies. And hence, DC-DC converter is accountable for converting unregulated DC voltage to a regulated DC output voltage in electronics and electrical devices. The applications of DC-DC converters have quite high in commercial and domestic operation like spaceship power system, desktop computers, laptop, DC motor drives, office equipment, telecommunications equipment, Uninterrupted Power Supply (UPS) etc. Unregulated DC voltage becomes as an input source for DC-DC converters which converts it into regulated voltage of different polarity and value at output side. One of the biggest challenges of working on such power converters is the generation of the heat in terms of nature for cooling. Thus, in such circumstance, high efficiency is to be achieved. Usually, maximum value of efficiency is achieved by an ideal DC-DC converter; but, actuality, 75% to 90% energy efficiency is achieved. For that reason, proper circuit factors like snubber capacitor, inductor and load resistance, switching device with suitable switching frequency are necessary in order to resist drainage of the power from the devices.

Many tools use multiple power supplies because selection of optimum voltage for certain application lessens losses and heat dissipation. Therefore engineers prefer the usage of voltages of different magnitudes in a system.

Traditionally, N independent converters were fabricated for N output voltages simply, whereas alternative option would be the usage of transformer with N secondary windings to distribute energy into the different outputs. However, the technique of N independent converters limits the size and cost constraints, as many power devices and controllers were required.

The next method of employing a transformer does not permit the self-regulating control of individual outputs. Often only one output was able to regulate through tight closed-loop control, while the other outputs were obtained through coupling of the secondary windings. Indeed, both methods necessitated N inductors or transformer windings, making the circuit bulky and costlier since inductors and transformers are typically the largest off-chip components. Serious cross-regulation problems also occurred as a result of leakage inductance and cross-coupling among windings.

Hence a need for multi-output DC-DC power converter having less cost fascinated because of its competence of interfacing with different sources, battery systems, and loads with different voltage levels.

The notion of non-isolated sextuple output hybrid converter is derivative of blending of basic dc-dc converters like Cuk, SEPIC and Zeta Converters. The remarkable topographies of structure are (i) single power semiconductor switch, (ii) six DC outputs with wide-ranging conversion ratio, (iii) transformerless converter systems, (iv) attainment of high output voltage without large duty ratio. The commended converter is explained in the subsequent portion. A new non-isolated sextuple output hybrid triad converter configurations is proposed to rule out the drawbacks of recent converters.

II. SEXTUPLE OUTPUT HYBRID TRIPLE CONVERTERS ARRANGEMENT

From the employment of traditional converters like Zeta, SEPIC and Cuk, present topology has been designed. The main benefit of the proposed configurations is that the converters with only one controllable power semiconductor switch is implemented simplifying the control strategies. The size is reduced and efficiency is improved because of absence of high-frequency transformer. This permits the two characteristics of the proposed configurations: simple structures, since single power switch is used and few active elements, and a simple driver circuit for single power switch that needs to be controlled. Figure 1 shows the generalized structure of sextuple output triad converter configurations. Figure 2 portrays the block diagram of sextuple output triad configuration using SI-SEPIC, Cuk and Zeta Converters. The circuit diagram of non-isolated sextuple output converter is depicted in Figure 3. The operational modes for proposed converter are stated below.

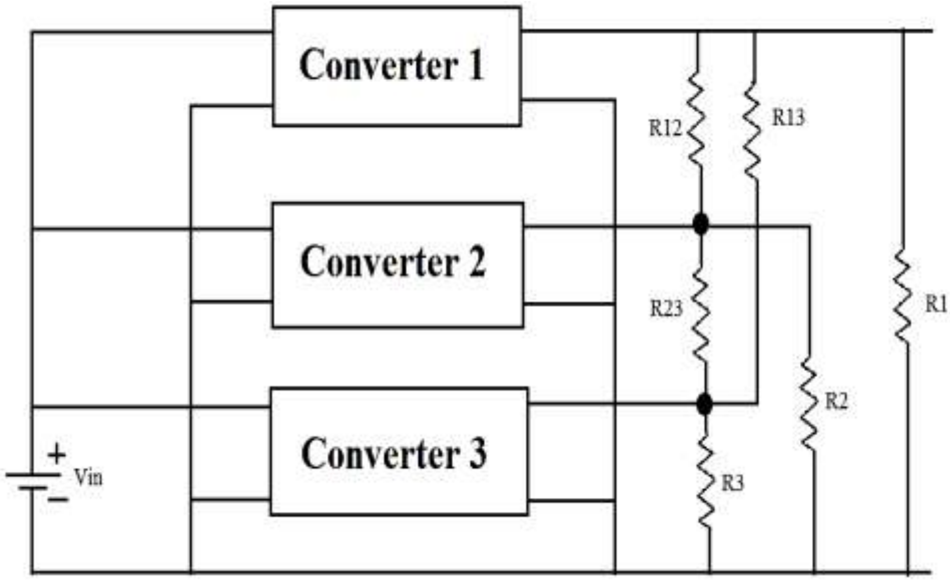


Fig. 1 Generalised structure of sextuple output triad converter configuration.

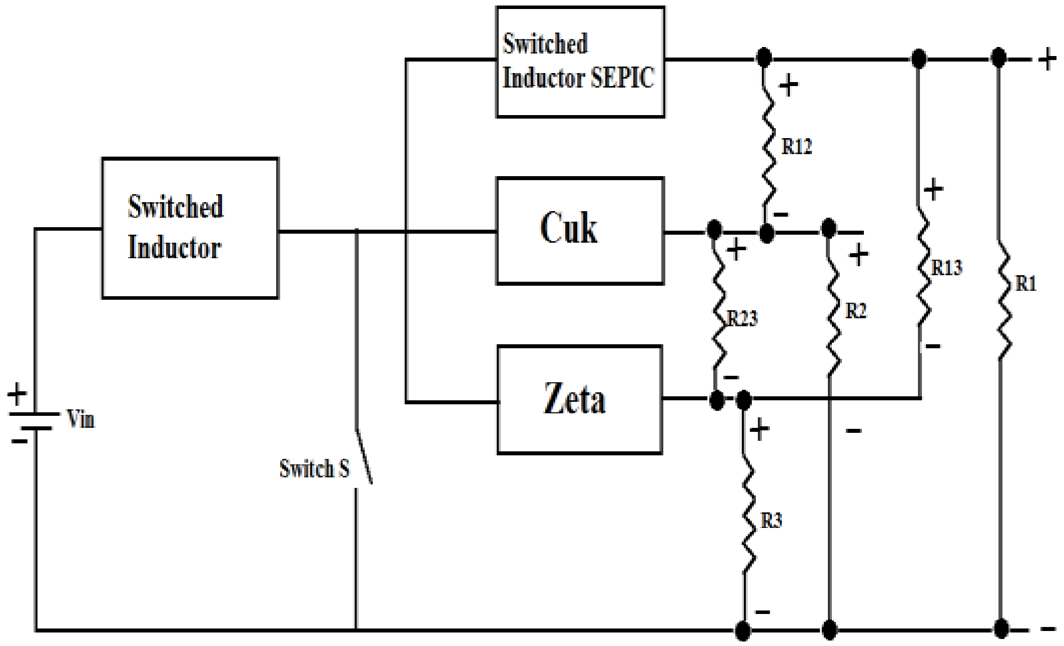


Fig. 2 Structure of sextuple output triad converter using SI-SEPIC, Cuk and Zeta Converters

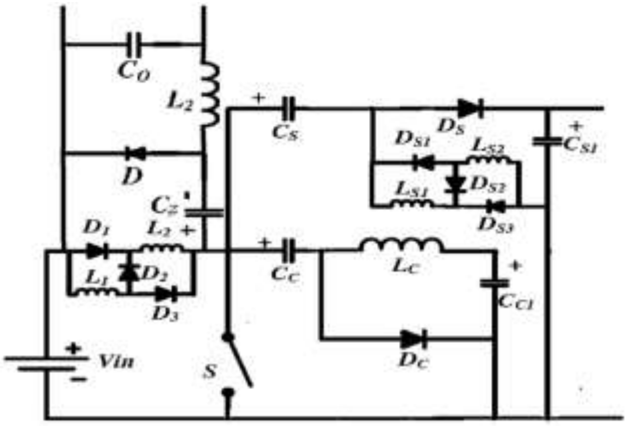
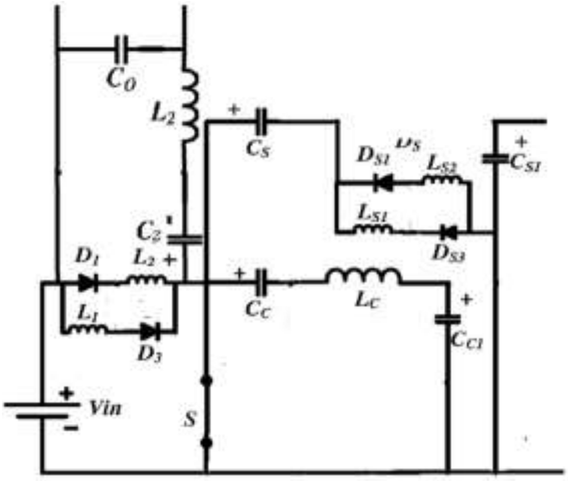


Fig. 3 Non-isolated Sextuple output converter.

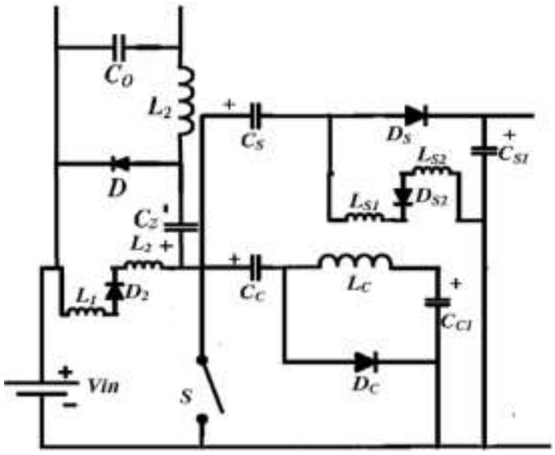
A. Mode of operation

The propounded topology has two modes of operation, i.e. when switch S is in ON state and when switch S is in OFF state. When the switch is ON, the energy from the input supply is stored by inductors L_1 and L_2; output side inductors L_C, L_Z and L_{S1} and L_{S2} of Cuk, Zeta and SI-SEPIC Converters respectively stores the energy as capacitors C_C, C_Z and C_S Cuk, Zeta and SI-SEPIC Converters respectively discharges. In the course of this interval, the diodes D_2, D_Z, D_C, D_S, and D_{S2} are in reverse bias and output is achieved from capacitors C_{Z1}, C_{C1}, and C_{S1}. The circuit for ON duration is described in figure 4(a).

When control switch is OFF, all the inductors charges all the capacitors in the circuit with the help of freewheeling diodes and energy is supplied to six loads with wide range of voltages. During this course, diodes D_1, D_3, D_{S1} and D_{S3} are in reverse bias. The subsequent circuit for OFF duration is in figure 4(b).



(a)



(b)

Fig. 4 Operational Modes of Non-isolated Sextuple output converter.

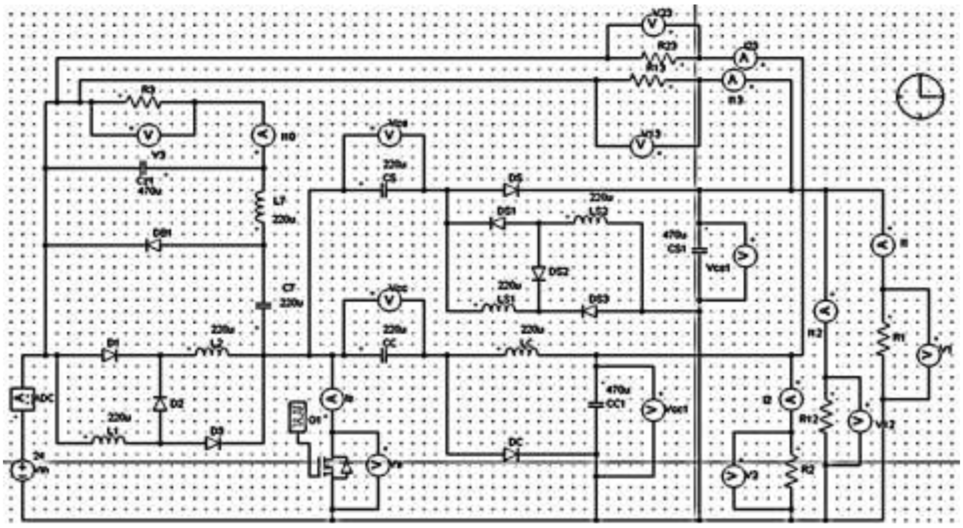


Fig.5 Simulation of Non-isolated Sextuple Converter

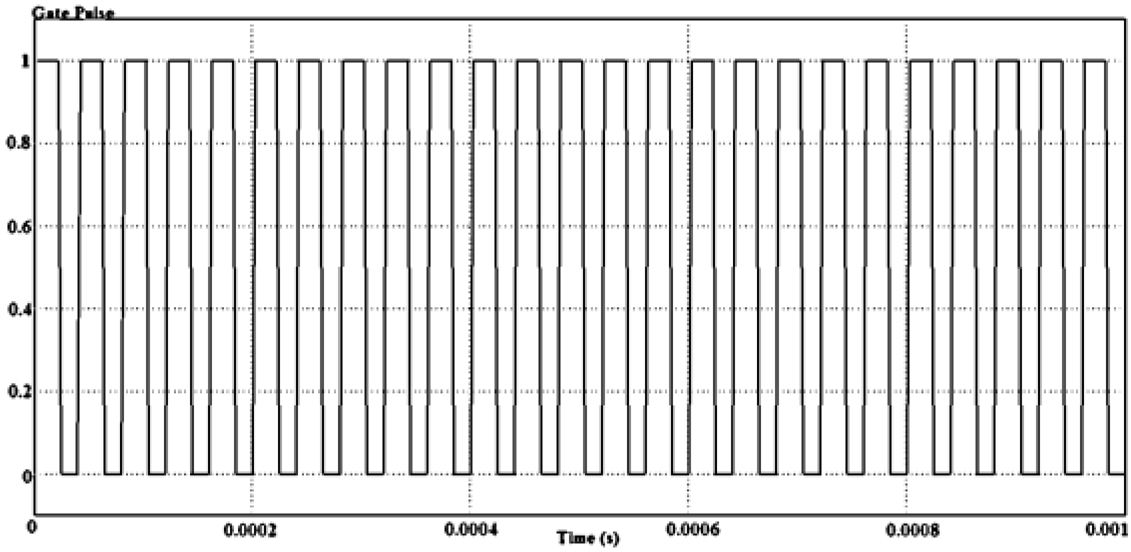


Fig.6 Gate Pulses Waveforms in Simulation

III. SIMULATION IMPLEMENTATION

Simulation results are simulated in PSIM Software using parameters input supply as 24 V, input power as 50 W, for duty ratio of 0.6 and switching frequency of 25 kHz. The Simulation Circuit is described in Figure 5. The Gate Pulses is portrayed in Figure 6 and input voltage waveforms are stated in Figure 7 and output voltage waveforms in Figure 8.

IV. HARDWARE IMPLEMENTATION

An experimental hardware is developed based on SI-SEPIC-Cuk-Zeta Combination converter. An input voltage of 24 V is supplied to the converter. The hardware is divided into different parts as shown in Figure 9. The white dotted part depicts the different parts of the hardware.

The switched inductor circuit consists of diodes and inductors having the inductance value of 200 µH. The diodes used here are hyperfast diodes RHR30120 manufactured by ON Semiconductor (initially Fairchild Semiconductor). As a single switch is controlling the circuit, here IGBT switch 40N60 is used.

In all the three converters, the diodes used are RHR30120 and inductors of inductance value of 200 µH are used as like the switched inductor circuit. The input capacitors of C_S, C_C and C_Z are selected such that the value is same i.e 220 µF and output side capacitors of C_{S1}, C_{C1} and C_{Z1} have value of 470 µF. The hardware results are depicted in Figure 10 and Figure 11.

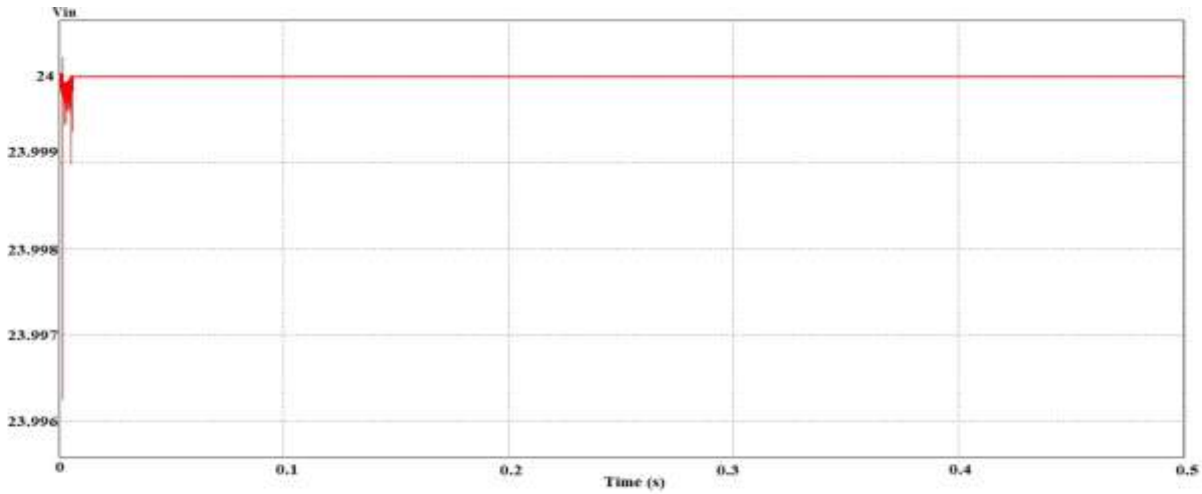


Fig.7 Input Voltage Waveforms

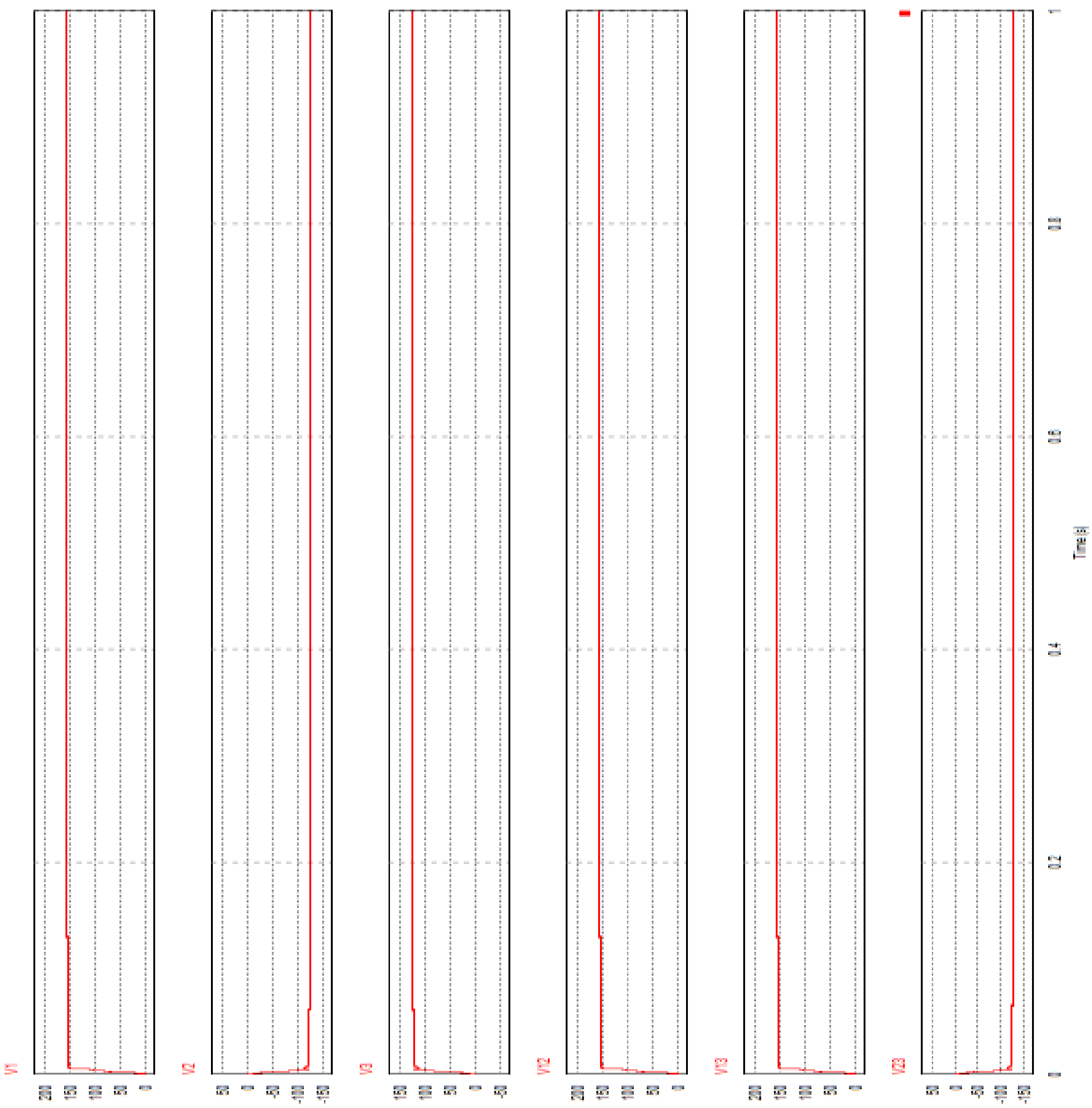


Fig.8 Sextuple output voltage waveforms. SI-SEPIC (V_1), Cuk (V_2), Zeta (V_3), SI-SEPIC-Cuk (V_{12}), SI-SEPIC-Zeta (V_{13}) and Cuk-Zeta (V_{23})

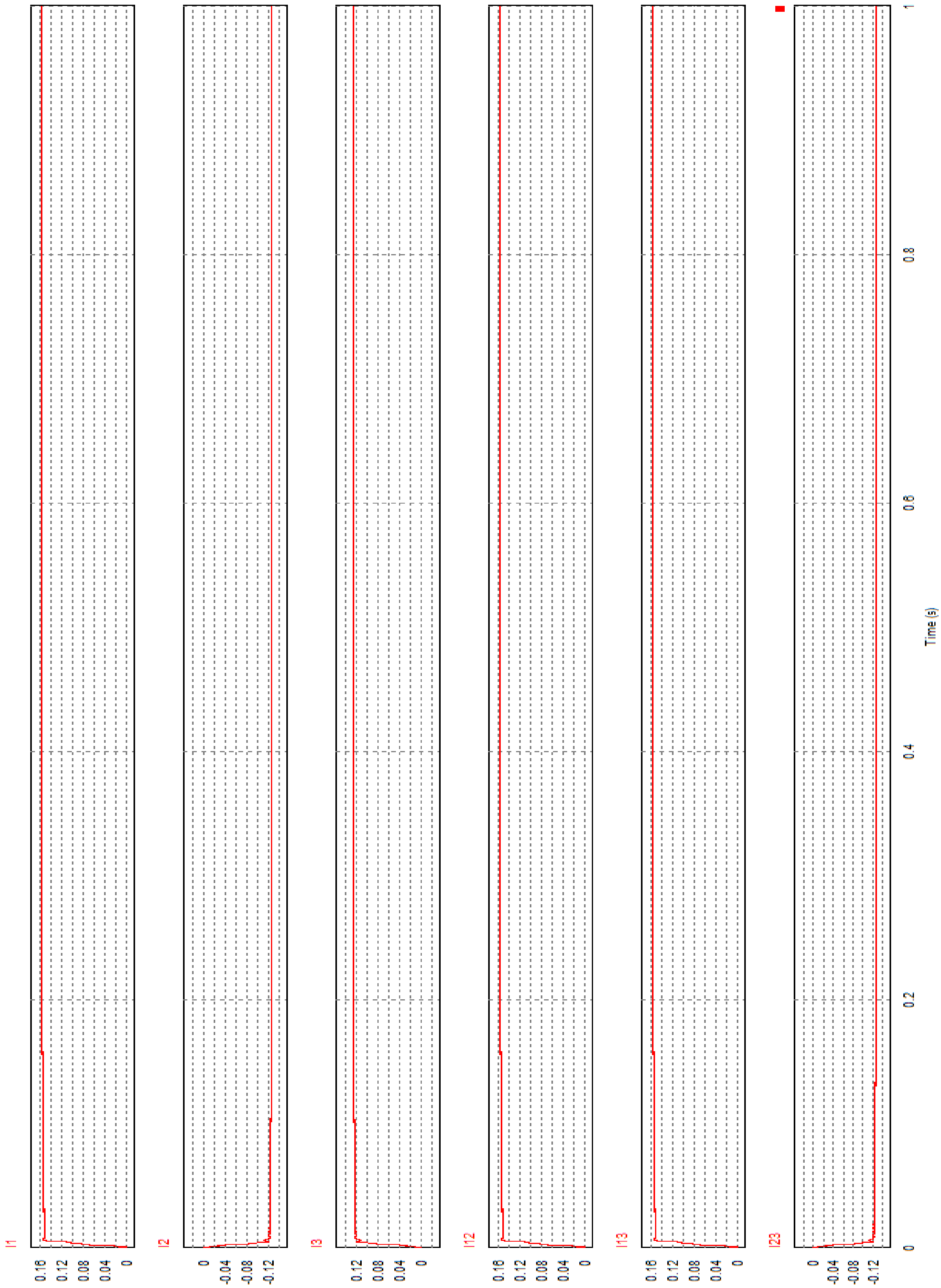


Fig.9 Sextuple output current waveforms. SI-SEPIC (I_1), Cuk (I_2), Zeta (I_3), SI-SEPIC-Cuk (I_{12}), SI-SEPIC-Zeta (I_{13}) and Cuk-Zeta (I_{23})

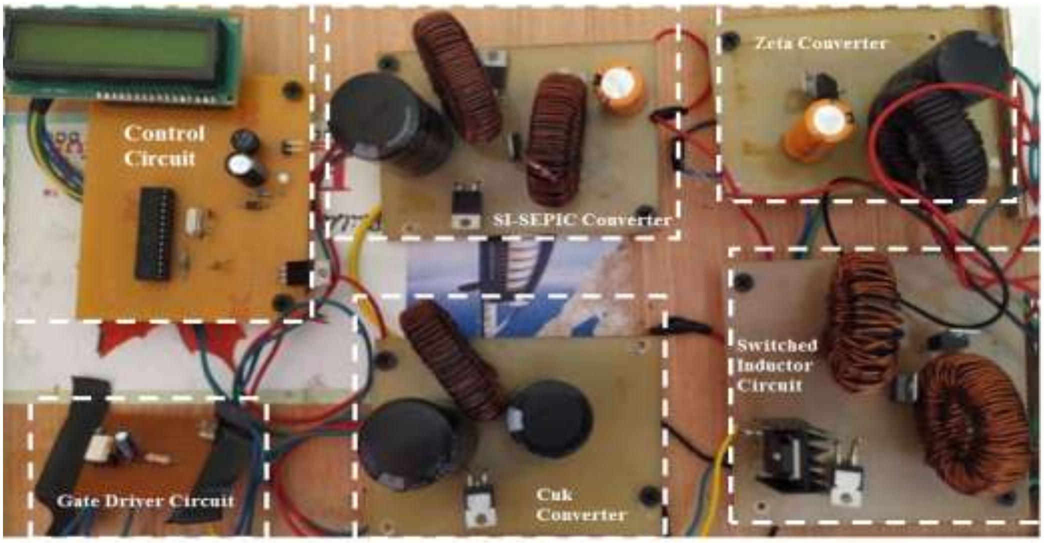


Fig.10 Hardware Implementation of Proposed Topology

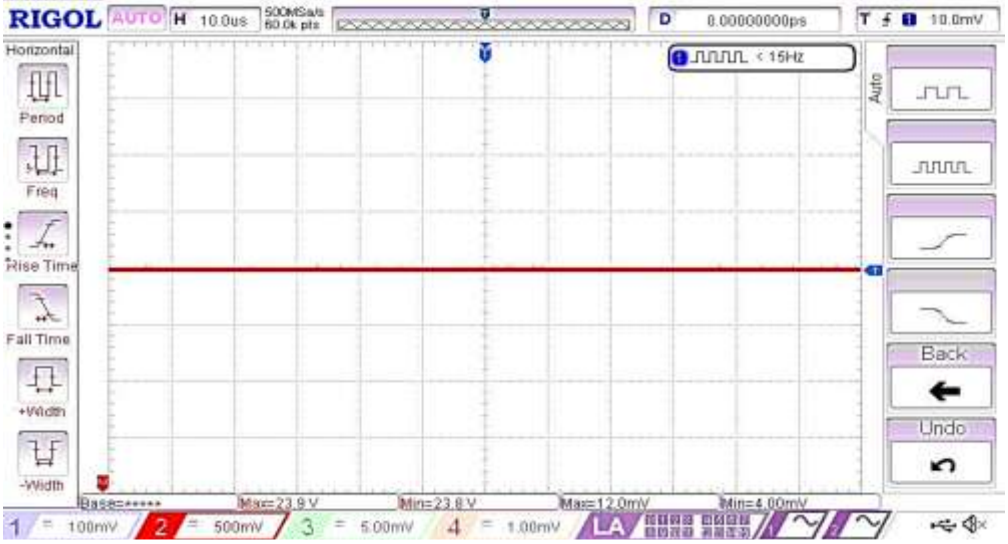


Fig.11 Experimental Input Waveform

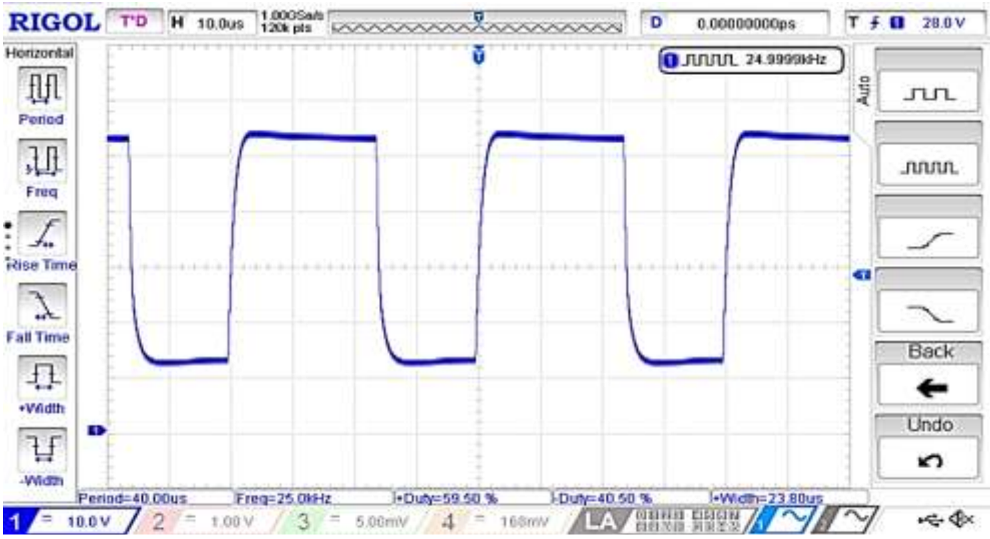


Fig. 12 Experimental Switching Pulse

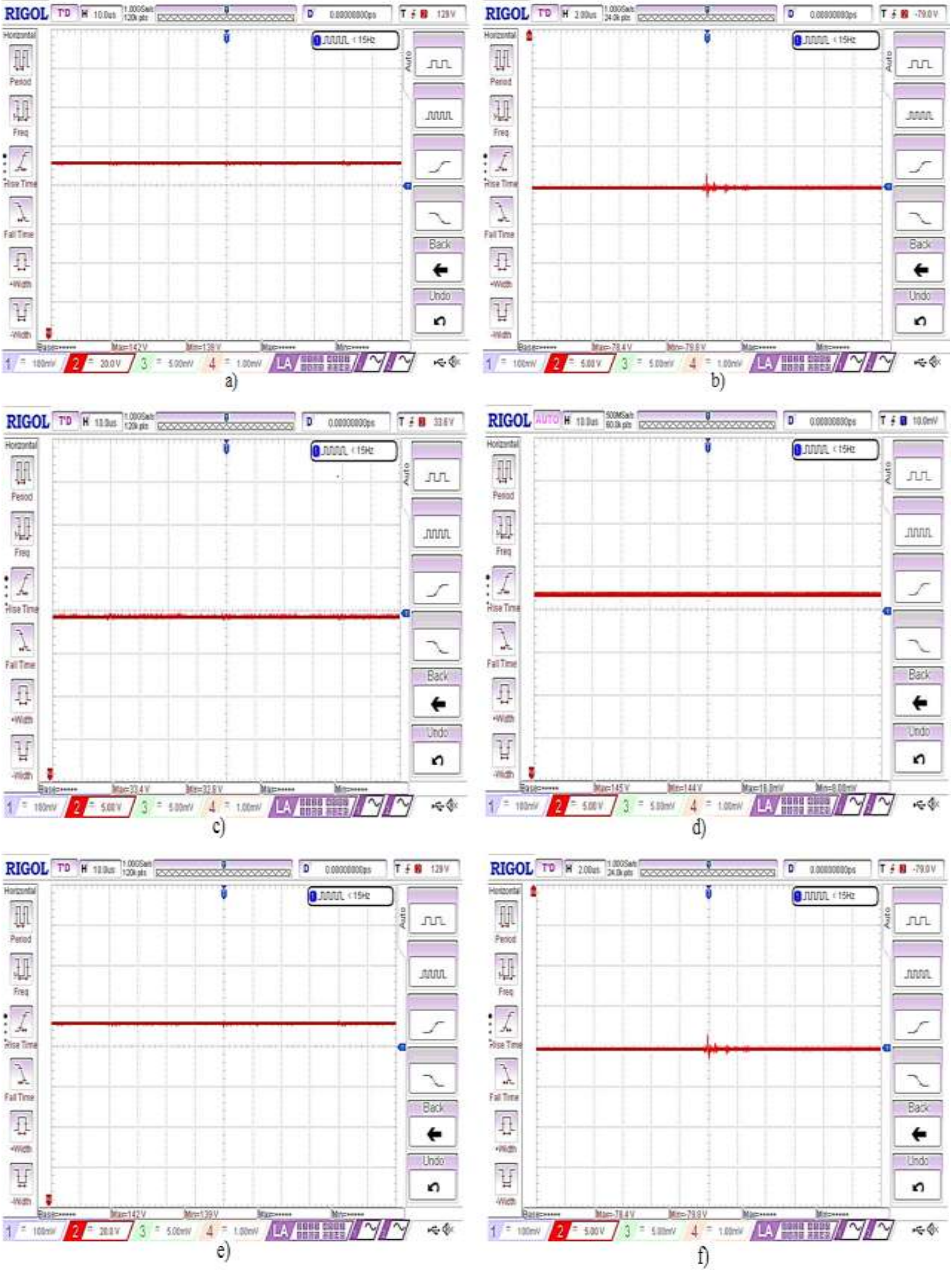


Fig. 13 Experimental Output Voltage Waveform a) SI-SEPIC b) Cuk c)Zeta d) SI-SEPIC-Cuk e) SI-SEPIC-Zeta f) Cuk-Zeta

When input source of 24 V is applied, SI-SEPIC converter gives output of 142 V, Cuk converter gives -78.4 V, Zeta Converter gives 33.4 V, SI-SEPIC-Cuk Combination gives 145 V, SI-SEPIC-Zeta Combination gives 142 V and Cuk- Zeta Combination gives -78.4 V.

V. CONCLUSIONS

A novel topology of non-isolated high gain converter from the combination of traditional non-isolated DC-DC converters is presented. The proposed converter structure achieves high voltage gain maintaining switch stress at low value. By varying the duty ratio, the topology can achieve high voltage gain. The number of outputs can be further augmented without the need of any additional switch.

A simulation of six-output- dc–dc converter configuration is performed in PSIM Software to validate its practicability, functionality and idea of suggested topology. An experimental prototype based on the Switched Inductor SEPIC-Cuk-Zeta combination converter is developed to certify the validity of proposed topology experimentally. The prototype followed the methodology described, which enabled the development of a power supply bank that consists of six different voltage levels. The experimental results have allowed verification of the proposed methodology for combination of basic converters.

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