iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 13 Issue: I Month of publication: January 2025

DOI: https://doi.org/10.22214/ijraset.2025.66356

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue I Jan 2025- Available at www.ijraset.com

Super-Lift Luo-Converter with Integration of Buck Converters for EV Applications

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Abstract: In this work, a super-lift and buck converter (SLBC) are integrated to provide a DC-DC multi-port converter. The single-input dual-output (SIDO) converter under consideration provides benefits over typical positive output voltage super-lifting while concurrently producing step-up and step-down voltages using buck and Luo converters.
The ripple in output voltages is reduced to a minimum in this construction by generating a dual output without using electromagnetic components.
The newly launched SLBC, presently, features simple layout and a reliable control strategy that offers a wide variety of output voltages. Additionally, in order to highlight the benefits of the proposed SIDO converter, a comparison with other equivalent setups is made.
Results from simulations and experiments show a significant decrease in conduction losses when compared to other SIDO converters in the similar circumstances. By running a number of simulations in the MATLAB/Simulink programme and putting a 7.5W prototype through testing in the lab, the operating correctness of SLBC is verified.
Keywords: Multi-port converters, Super lift and buck converters, Voltage lifter circuits, Electric vehicle

I. INTRODUCTION

In response to increasing concerns about environmental pollution and the depletion of fossil fuels, the development of electric vehicles (EVs) has become an increasingly popular trend. The adoption of high-performance and dependable power electronics systems is essential to enhancing the performance and efficiency of EVs. In this context, a proposed solution for the voltage conversion needs of EVs is the Super-lift Luo-converter with the integration of Buck converters (SLBC).
High step-up voltage gain, minimal switching losses, and low output voltage ripple are benefits of the suggested converter. In order to assess the suggested converter's performance and suitability for EV applications, this project will construct and simulate it. The simulation findings will support the suggested converter's viability and effectiveness and offer guidance for applying it to real-world EV systems.
In recent years, DC-DC multi-port converters (MPCs) have been a hot topic due to the growing industry of electric vehicles (EVs) and higher penetration of renewable energy sources (RESs) such as photovoltaics (PV) incorporated with wide voltage ranges. DC-DC MPCs are divided into two different structures: multi-inputs and multi-outputs. Multi-inputs structures are applied to supply a load utilizing different sources.
On the other hand, multi-outputs supply various voltage levels by a single source. These types of converters are used in RESs, mobile transmission, LED drivers and EVs. The field of DC-DC converters has been interested in single input dual output (SIDO), or single-input multi-output, converters. In the literature, a variety of architectures have been proposed, including those with connected inductors, single-inductor multi-output arrangements, and multi-port transformers. However, these architectures have drawbacks including large components, significant losses, and complex drive and control circuits.
When compared to other topologies with an identical design, the SLBC exhibits a considerable reduction in conduction losses. The suggested construction is capable of meeting the varied voltage requirements of electric vehicle systems. The SLBC offers a broad variety of output voltages and has an effective control strategy. Additionally, it eliminates the requirement for electromagnetic components to provide two outputs, hence simplifying the design. Also, the proper functioning of the SLBC in producing two separate step-up and step-down outputs with little output ripple is confirmed by simulations and experimental findings.
In this regard, the SLBC is a promising structure for SIDO converters, providing benefits in terms of design simplicity, minimal conduction losses, and adaptability in output voltage range.

II. SYSTEM CONFIGURATION

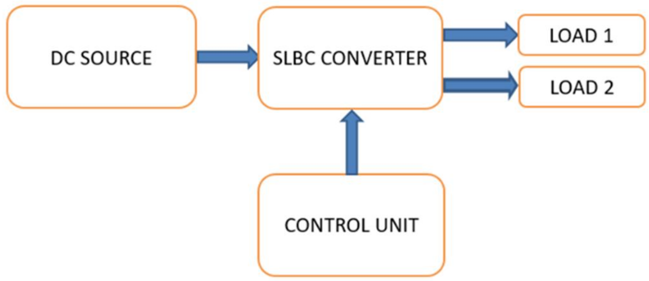

Fig. 1. Block diagram of the system

Block diagram of proposed DC-DC multi-port converter consist of DC source, SLBC converter, control unit, loads. The block diagram of proposed converter is shown in Fig.1.This paper creates a SIDO DC-DC converter with two different boost and buck outputs. Various components in an EV, such as the motor, sound system, and lamps, require different voltages. Therefore, the appropriate application for promoting the model is the EV. Recommended DC-DC Converter Integrated Super lift and a Buck Converter (SLBC) produce both boost and buck outputs from a single input. The output power is increased by the super lift method. In this way, high gain voltage can be created with a simple structure without an additional transformer or circuit for control, regulation. Therefore, the generated output voltage has better power efficiency. In the proposed converter, the positive output super-lift Luo-converter is utilized for the step- up output. Meanwhile, the proposed SIDO converter can provide step-down voltage. The structure of the proposed converter is shown in Fig.2

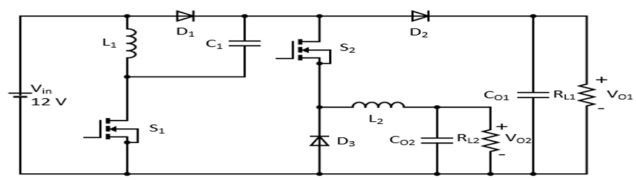

Fig. 2. Schematic diagram of the system

A super-lift Luo-converter is a modification of the basic Luo-converter design that includes an additional voltage boost stage, which allows for even higher step-up voltage ratios. By integrating the buck converter (another type of DC-DC converter), the output power can be more controlled and efficient; this is electric vehicles Fab. In electric vehicles, the power electronics system must convert the high voltage of the battery to the low level required by the various vehicle components. The super lift converter can increase the battery voltage to a higher level, which can be reduced to a suitable level for special components by the buck converter. This approach reduces power loss and maximizes overall efficiency, which is especially important in electric vehicles where battery life and range are important. Overall, the super-lift Luo converter with integrated buck converter can be a more efficient and compact solution for high-power DC-DC conversion in electric vehicles. The Luo converter and buck converter combination uses the Luo converter as a high-voltage, high-gain stage and the buck converter as a low-voltage, low-gain stage. The output of the Luo converter is connected to the input of the buck converter, and the combination of the two converters results in an efficient and accurate step-up and step-down power conversion.

A. *The proposed SLBC operation modes*

1) *MODE-1*

- In this modes switches S_1 and S_2 are ON
- Switch S_1 connects the input voltage to inductor L_1.
- Inductor L_1 starts to store energy in the form of a magnetic field
- This causes a voltage increase across the inductor L_1, which is then transmitted through diode D_1 to capacitor C_1.
- Capacitor C_1 charges through diode D_1, and a portion of this voltage passed to switch S_2 which conducts and charges inductor L_2,
- Capacitor C_{O2} also charges with inductor L_2 and output is taken across resistor R_{L1}.
- This time Diodes D_2 and D_3 are reverse biased.

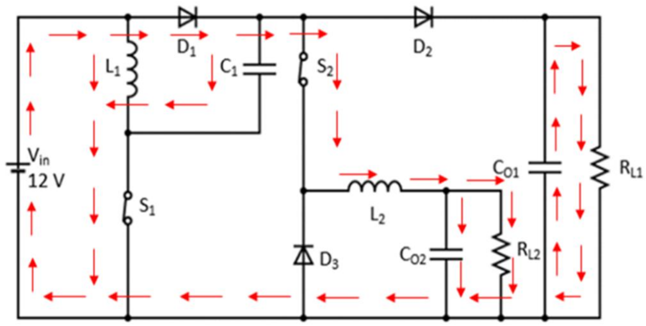

Fig. 3 Mode -1 of proposed SLBC converter

2) MODE-2

- In this mode switch S_1 is ON and S_2 is OFF
- When S_2 is OFF, inductor L_2 starts to discharge through diode D_3 and charges capacitor C_{O2}.
- Diode D_3 is now forward biased.
- Output is taken across resistor R_{L2}.
- This time L_1 and C_1 continues charging as in mode-1 due to S_1 is turned on.

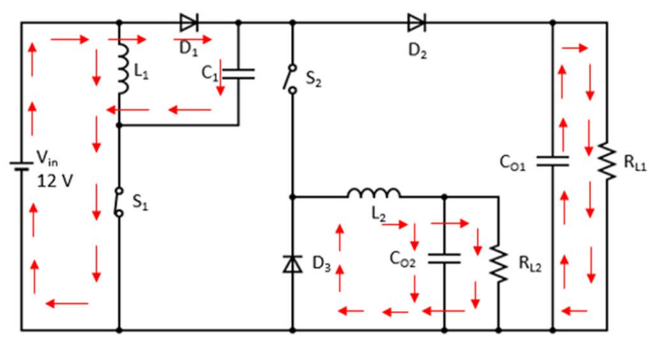

Fig. 4 Mode -2 of proposed SLBC converter

3) MODE-3

- In this mode switches S_1 and S_2 are OFF.
- When switch S_1 is turned off, Inductor L_1 starts to discharge as its polarity is reversed.
- Diode D_2 is now forward biased and capacitor C_{O1} charges.
- Super lifted output voltage V_{O1} shows across load $R_{L1.}$
- This V_{O1} is the sum of V_{in}, V_{L1} and $V_{C1.}$
- Switch S_2 remains turned OFF in this mode so inductor L_2 continues to discharge through Diode D_3 and charges capacitor C_{O2}.
- The average value of C_{O2} charging in two modes is taken as the step downed output voltage $V_{O2.}$

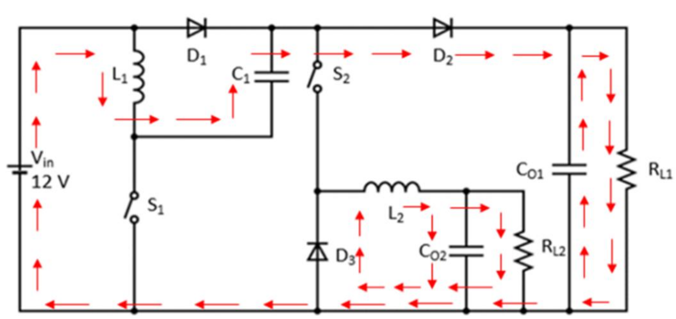

Fig.5 Mode -3 of proposed SLBC converter

III. PERFORMANCE ANALYSIS OF THE SYSTEM

In our Super-lift Luo converter integrated buck converter project, we use MATLAB to simulate and control the performance of our proposed converter. MATLAB simulation is a powerful tool widely used in the electrical and electronic engineering industry to analyze, design and test different circuits and systems. It provides a comprehensive introduction to the design, simulation and analysis of complex systems, including electrical power systems. Through simulation we can analyze the behavior of the converter under different operating conditions, optimize its performance and evaluate its efficiency.

In the simulation model of the Super-lift Luo converter with integrated buck converter, closed-loop control of the MOSFET switch is performed. This provides better control of the output voltage and keeps it in range even if there are variations in the input voltage or load. The closed loop control system includes a feedback loop that monitors the output voltage and compares it to a reference voltage. Any difference between the two voltages is fed into the controller, which adjusts the duty cycle of the MOSFET switches in order to maintain a stable output voltage. The controller used in the simulation is a proportional-integral-derivative (PID) controller that takes into account the current error and the rate of change of the error experience and adjusts the duty cycle accordingly. The parameters of the PID controller can be tuned to optimize the response time and stability of the system. The simulated diagram is shown in the fig.6.It enables independent controlling of two switches in the SLBC converter. As we mentioned above closed loop control mechanism ensures regulating of super-lifted output voltage and buck output voltage effectively. By correct tuning of PID controller separate, control of two switches are possible. PID control helps to control two switches independently to keep the system running at high efficiency. The PID control algorithm adjusts the duty cycle of the switches to maintain the desired voltage while minimizing the effects of interference and noise in the system. The simulated model of SLBC have six times gain for the super-lifted output voltage and a wide range of voltage for buck output.

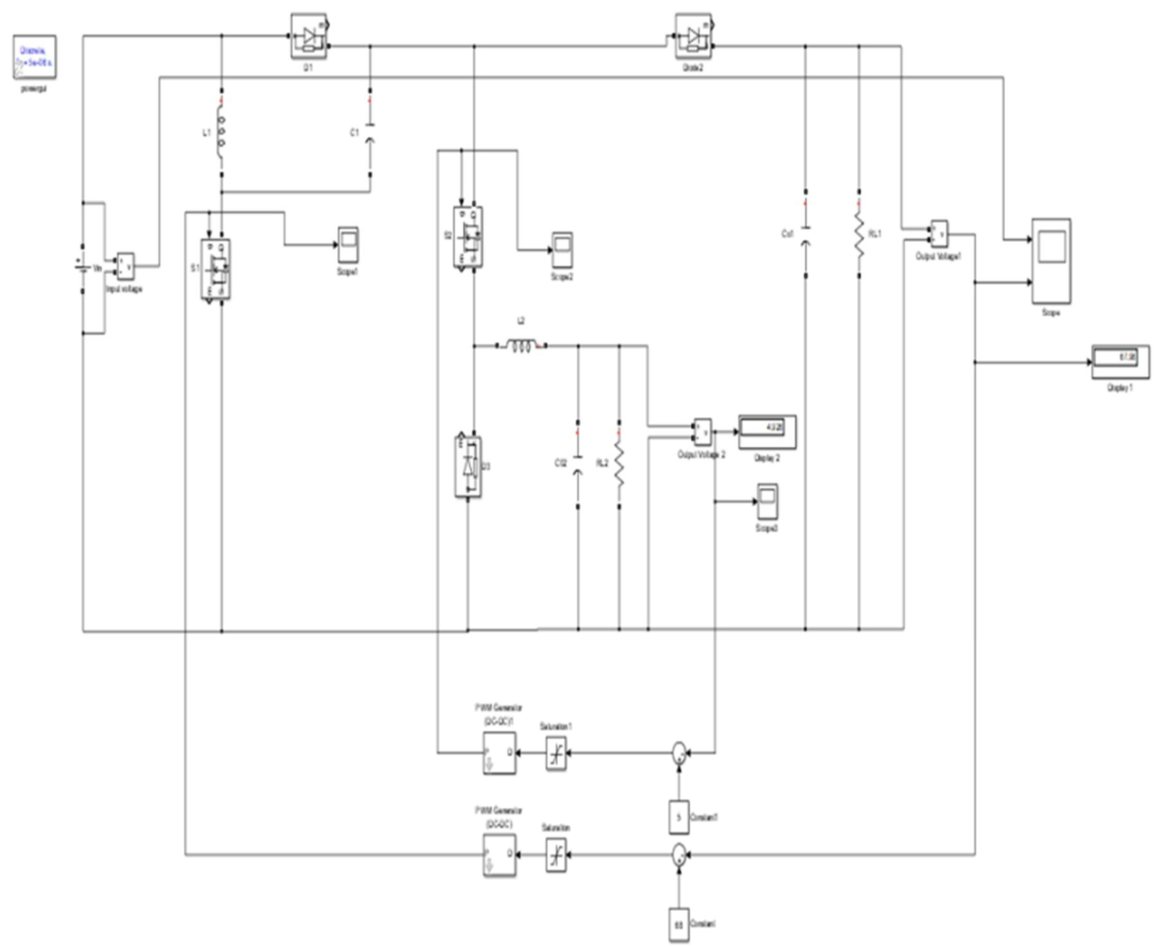

Fig.6 Simulated circuit diagram

Simulation waveforms are important for understanding the behavior of the super-lift Luo-converter with the integration of buck converter. Input voltage waveform shows the behavior of the input voltage over time and output voltage waveform shows the behavior of the output voltage over time. Simulated waveforms can provide information about the ripples in the circuit. These waveforms provide a visual representation of the circuit's behavior and can be used to analyze the circuit's performance under different operating conditions. The simulation waveforms obtained for SLBC is shown fig.7 and fig.8.

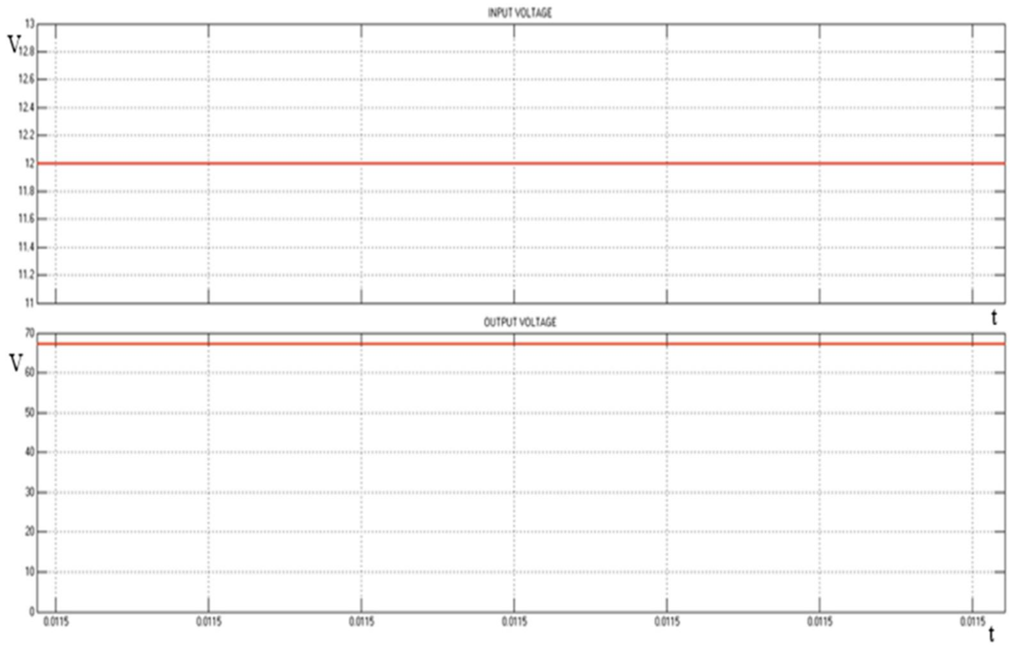

Fig.7 Input voltage waveform and super-lifted output voltage waveform

Fig.7 includes input voltage waveform and super-lifted output voltage waveform of the simulated model of SLBC. Fig 8 shows step downed (buck) output voltage waveform of the simulated model of SLBC.

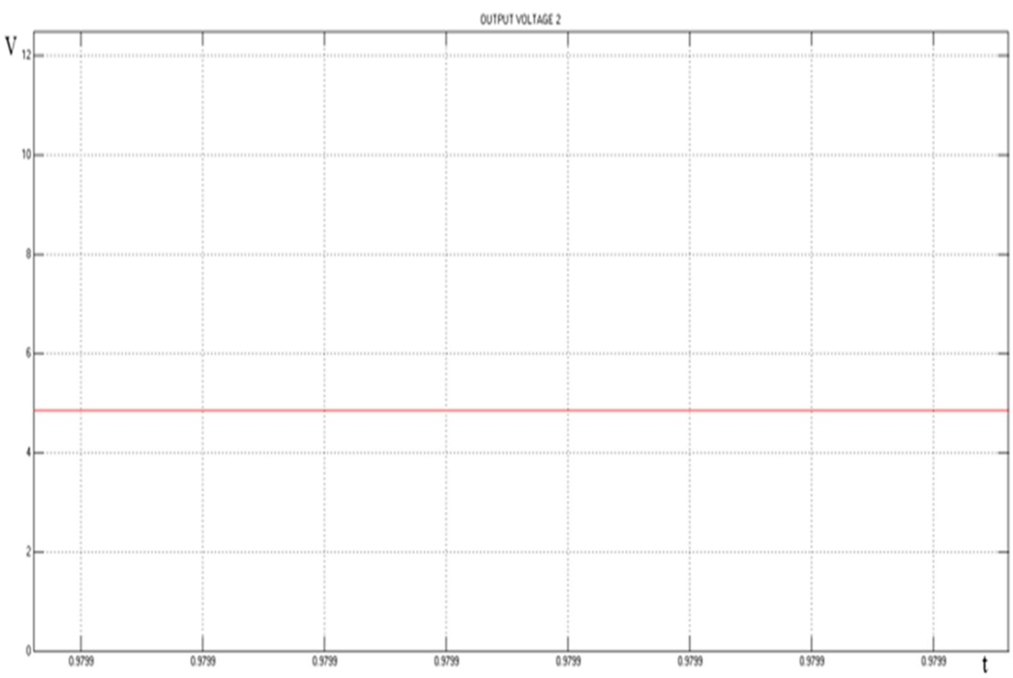

Fig.8 Step downed (buck) output voltage waveform

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue I Jan 2025- Available at www.ijraset.com

IV. DESIGN OF THE SYSTEM

This section discuss the design of a 10w SLBC converter prototype. The rating and specifications of components used design of prototype are as follows:

A. *Design Of Super-Lift LUO Converter*

Input voltage V_{in} = 12V
Output voltage V_{O1}= 68V
Output power=5W
Switching frequency = 30kHz
Efficiency = 90%

Voltage transfer gain $= \frac{V_{O1}}{V_{in}} = \frac{2-D}{1-D}$

$= \frac{68}{12} = \frac{2-D}{1-D}$

Duty ratio D = 0.786
Here P_{in} = 5.56 W
Inductor current I_L = 0.463A
Current ripple of L_1 is = 40% of I_L
= 0.185 A

Desired size of inductor $L_1 = \frac{V_{in}DT}{\Delta I_L}$

$= \frac{12 \times 0.786 \times 33.33 \times 10^{-6}}{0.185}$

=1.69mH

Desired size of capacitor $C_1 = \frac{(1-D)V_O}{f\,\Delta V_O\,R}$

$= \frac{(1-0.786)\times 68}{30000\times 68\times 0.01\times 924.8}$

= 7.71μF

Desired size of capacitor $C_{O1} = \frac{I_O \times D}{f_s \Delta V_O R}$

$= \frac{(5/68)\times 0.786}{30000\times 68\times 0.01}$

= 2.83μF

B. *Design Of Buck Converter*

Input voltage Vin = 68V
Output voltage V_{O2}= 5V
Output power=2.5W
Switching frequency = 30kHz
Efficiency = 90%
Here P_{in} = 2.77W

Duty ratio $D = \frac{V_{O2}}{V_{in}}$

$= \frac{5}{68}$

= 0.0735

Desired size of inductor $L_2 = \frac{(V_{in} - V_{O2})DT}{\Delta I}$

$= \frac{(68-5)\times 0.0735\times 33.33\times 10^{-6}}{0.1\times 0.4}$

= 3.85mH

Desired size of capacitor $C_{O2} = \frac{I_O}{\Delta V 4 f}$

$= \frac{(2.5/5)}{0.01\times 5\times 4\times 30000}$

= 83μF

To justify the theoretical analysis of the proposed SLBC converter producing a boosted 68V and step downed 5V output voltages from a 12V dc input supply prototype is developed in laboratory. The prototype operating at a switching frequency of 30 kHz and have a 7.5W output power. For high-speed and high-power operation MOSFET IRF530 and p55 are utilized in our prototype as power switches. The developed hardware is shown in the fig.9.

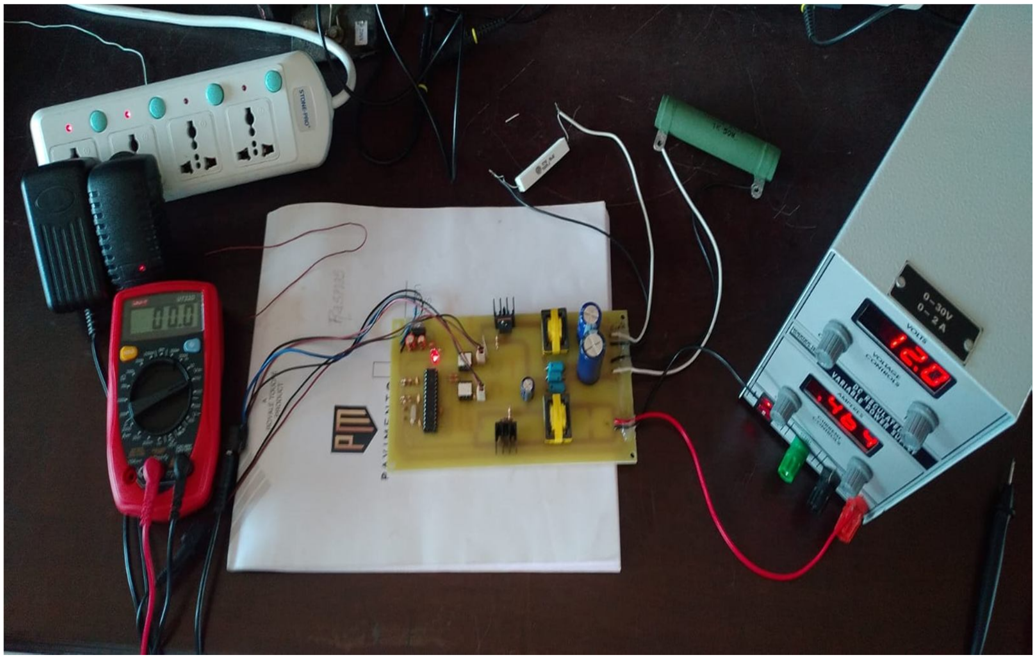

Fig.9 Experimental prototype of proposed SLBC converter

The specifications of the components used in prototype are listed in table 1

Table 1 Design specification of the prototype

PARAMETERS	VALUE	PARAMETERS	VALUE
Input voltage, Vin	12V	Capacitor, C_1	10μF
Output voltage 1, V_{O1}	68V	MOSFET 1 (BOOST)	IRF530 (100V, 14A)
Output voltage 2, V_{O2}	5V	MOSFET 2 (BUCK)	P55 (60V, 50A)
Total output power, P_O	7.5W	Load R_{L1}	1000Ω
Switching frequency, fs	30000Hz	Load R_{L2}	100Ω
Inductor,L_1	1.6mH	Diode, D_1	HF04
Inductor, L_2	3.6mH	Diode, D_2	HF04
Capacitor, C_{O1}	4700F, 50V	Diode, D_3	HF04
Capacitor, C_{O2}	4700F, 35V	Crystal Oscillator	8MHz

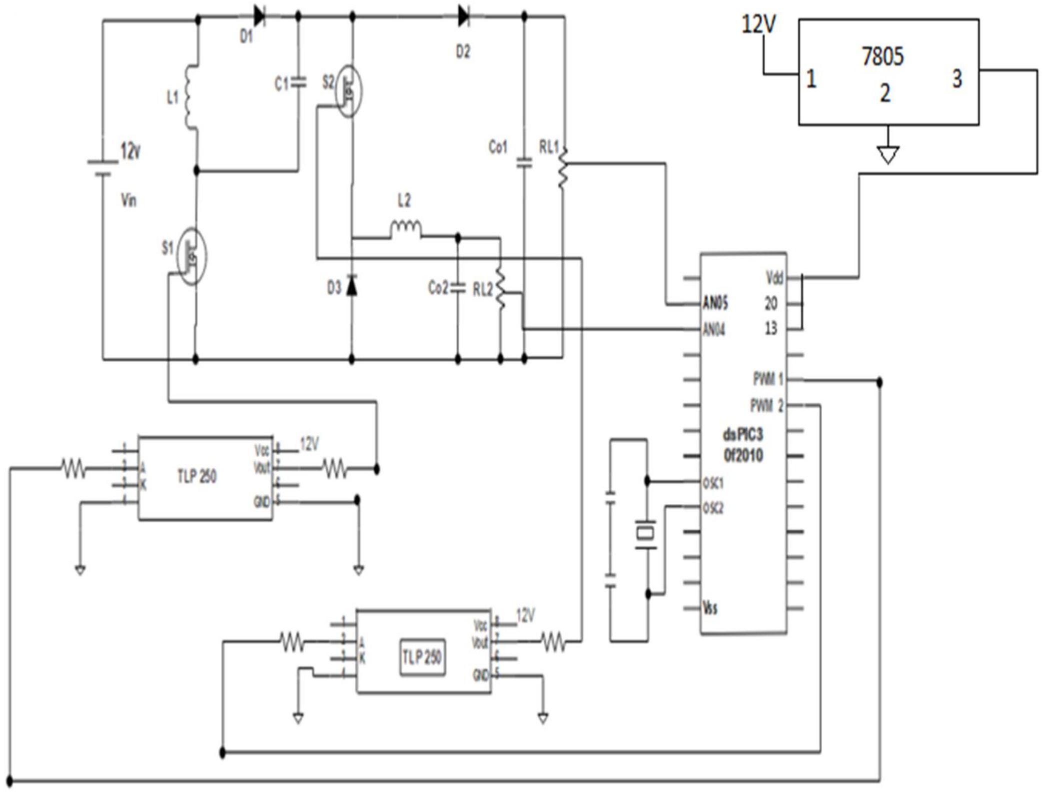

Fig10 Schematic diagram

The output voltage of the proposed SLBC converter prototype made in the laboratory is shown in the fig.11 and fig 12 .The output voltage measured across the 1000Ω load is 68V is shown in figure 5.5.3, which is the super lifted output. In the proposed converter we achieved six times output voltage gain. The output voltage measured across the 100Ω load is 5V as shown in fig.5.5.4, which is the buck output. We also understood that the range of buck output is increased from minimum to maximum value. Two outputs having almost less amount of ripples are resulted in the voltage waveforms. The proposed SLBC converter is proved to be more efficient (90%) and have simplest design with lesser number of components ensures its practicality.

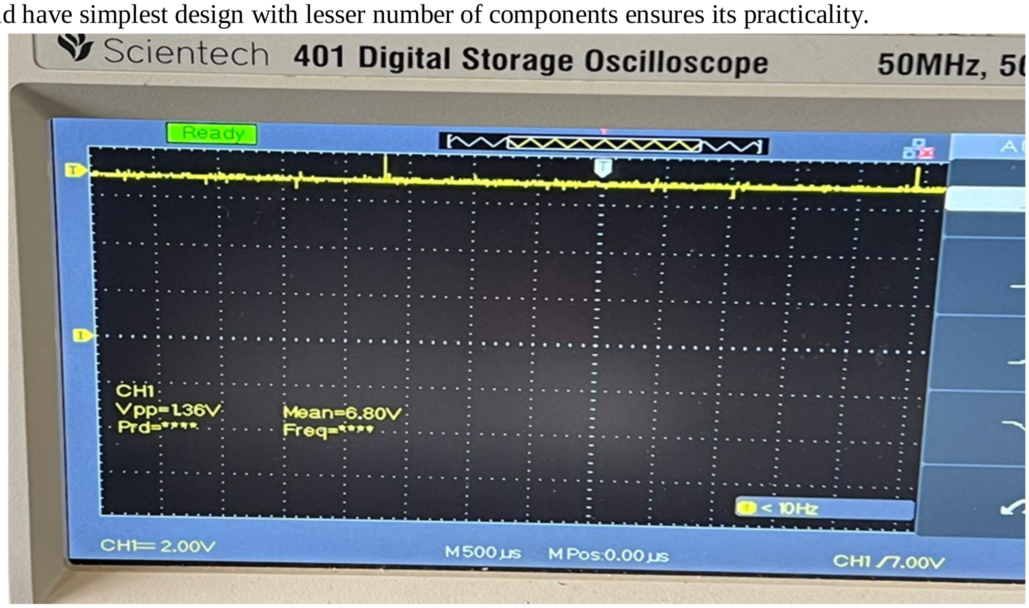

Fig.11 Super-lifted output voltage waveform of the prototype

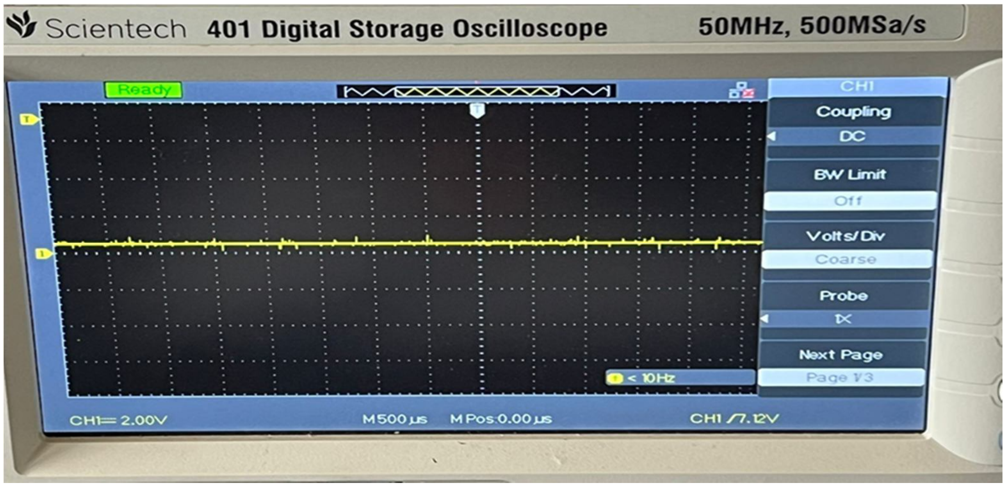

Fig.12 Buck output voltage waveform of the prototype

V. CONCLUSION

In conclusion, it has been successful to build a super-lift Luo-converter with the integration of buck converters for use in electric vehicle applications. The research offers a remedy for both high-voltage and low-voltage uses in an electric vehicle, increasing its dependability and efficiency. The project was able to show that the Super-lift Luo-conversion and Buck converter are successful at generating the appropriate output voltages via the use of simulation and hardware implementation. The MOSFET switches are able to be independently controlled by the closed-loop control system utilizing the PID controller, leading to reliable and effective operation. Our suggested converter successfully achieves its primary goals of generating a wide range of voltage, enhanced voltage gain, and minimal conduction losses without the use of electromagnetic devices. It is possible to transmit power and regulate voltage effectively by using a single input multi output (SIMO) converter with various output voltage levels. Electric vehicles can utilize use of the converter's properties, such as high efficiency, decreased size and weight, and increased dependability, according to the suggested design and specifications. Advanced control techniques can also be used to further optimize the suggested converter's functionality and efficiency. Overall, the SIMO DC-DC converter under consideration has enormous potential applications in the fields of electric vehicles and renewable energy systems.

VI. ACKNOWLEDGEMENT

I take this opportunity to express my deepest gratitude and appreciation to all those people who made this main project report work with words of encouragement, motivation, discipline and faith. First and foremost, I am grateful to the lord who gave me sufficient potential to make this seminar report a success.I would like to thank Dr. SANGEETHA, Principal, Vedavyasa Institute of Technology for providing me with the best facilities and atmosphere for the Seminar report completion and presentation. I express our deep gratitude to Mr**.** BALAKRISHNAN PILLAI, Head of the Department, Electrical and Electronics Engineering, Vedavyasa Institute of Technology, Malappuram for his immense support and guidance. I have great pleasure in expressing my deep sense of gratitude and indebtedness to our guide Mrs. SREELAKSHMI P K, Asst.professor, Department of Electrical and Electronics Engineering, Vedavyasa Institute of Technology, Malappuram for his invaluable guidance through every stage of our work and timely advice. Finally, I take this opportunity to express my thanks to the teaching and non teaching staff in Department Electrical and Electronics Engineering, for their valuable help and support for making the seminar report a success, I am grateful to all my classmates for their help and encouragement..

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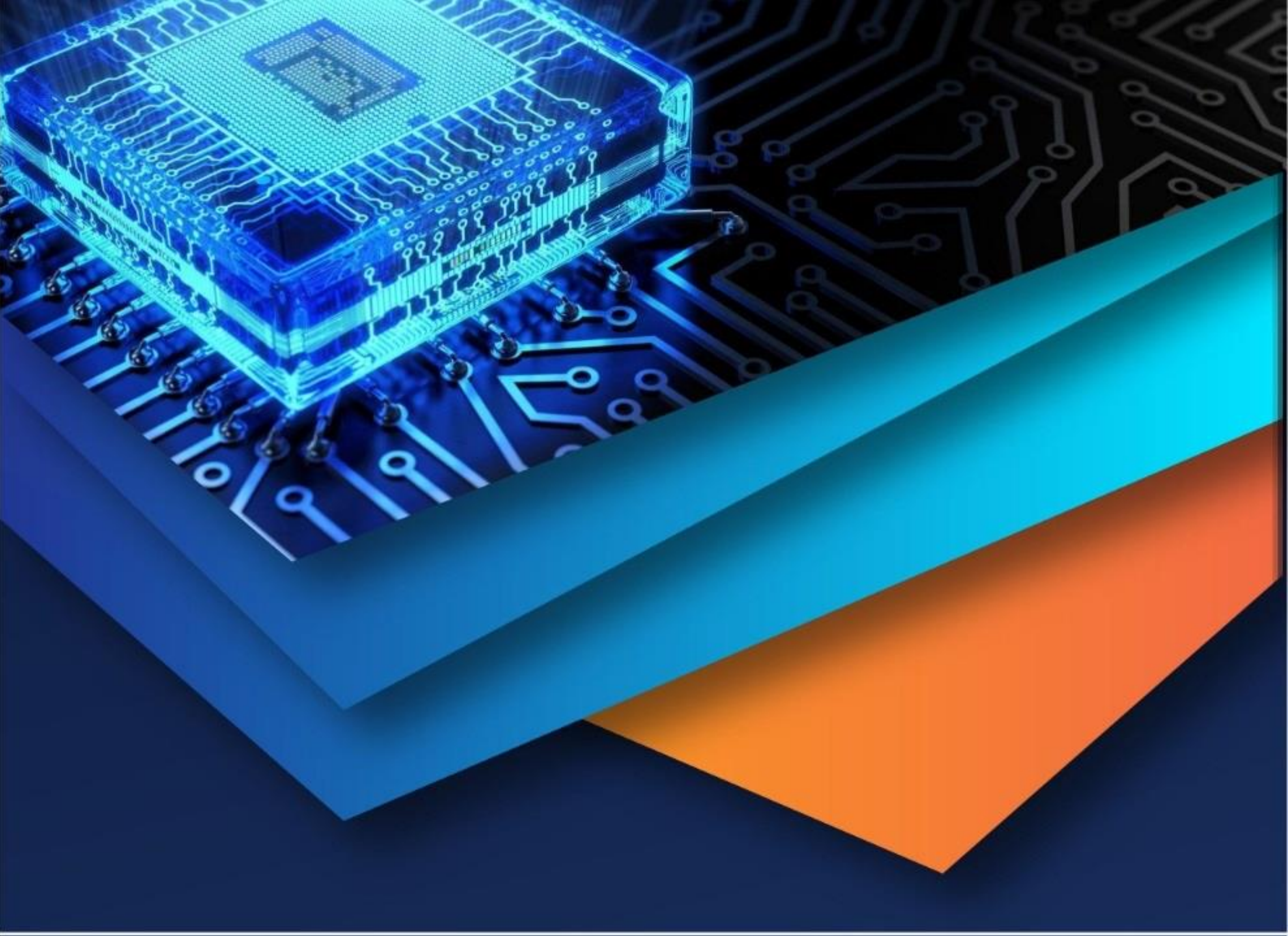

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