DESIGN AND ANALYSIS OF BOOST CONVERTER USING SiC MOSFET AT HIGH DUTY RATIO

A PROJECT REPORT

Submitted by

ARUN KUMAR S	**190901017**
HARIPRASAD R	**190901044**
HARSHA VARDHAN G	**190901045**

in partial fulfillment for the award of the degree of

BACHELOR OF ENGINEERING

ELECTRICAL AND ELECTRONICS ENGINEERING

DEPARTMENT OF

ELECTRICAL AND ELECTRONICS ENGINEERING

RAJALAKSHMI ENGINEERING COLLEGE

ANNA UNIVERSITY, CHENNAI

DECEMBER 2022 TO APRIL 2023

BONAFIDE CERTIFICATE

Certified that this project report **"DESIGN AND ANALYSIS OF BOOST CONVERTER USING SiC MOSFET AT HIGH DUTY RATIO"** is the bonafide work of **"ARUNKUMR S (190901017), HARIPRASAD R (190901044), HARSHAVARDHAN G (190901045)"** who carried out the project work under my supervision**.**

SIGNATURE	**SIGNATURE**
Dr. C. KAMALAKANNAN, **HEAD OF THE DEPARTMENT,**	**Dr. T.S.SARAVANAN,** **SUPERVISOR,**
Professor,	Assistant Professor (SG),
Department of Electrical and	Department of Electrical and
Electronics Engineering,	Electronics Engineering,
Rajalakshmi Engineering College, Thandalam,	Rajalakshmi Engineering College, Thandalam,
Chennai- 602105.	Chennai- 602105.

Submitted for viva-voce held Examination on ______________

INTERNAL EXAMINER **EXTERNAL EXAMINER**

ABSTRACT

Generally, Boost converters are mainly used to step up voltage to a certain higher level. In this prototype SiC MOSFET is used as a switching device so that it can withstand higher voltage. The conventional boost converter has limitation when operated at high duty ratio, to overcome this high voltage gain converter is proposed with SiC MOSFET. Silicon Carbide (SiC) device is most preferred because of larger current carrying capability, higher voltage blocking capability, high operating temperature and less static and dynamic losses than the traditional silicon (Si) power switches. The converter is designed and simulated using LTspice simulation software with CREE SiC MOSFET model and compared with Si MOSFET of same voltage and current rating. Finally, a hardware prototype with Si and SiC devices is implemented to validate the simulation results.

ACKNOWLEDGEMENT

We wish to express our deep sense of gratitude to our guide **Dr.T.S.SARAVANAN,** Assistant Professor (SG), Department of Electrical and Electronics Engineering, providing an opportunity to work on this project **"DESIGN AND ANALYSIS OF BOOST CONVERTER USING SiC MOSFET AT HIGH DUTY RATIO".** We also thank him for his enthusiastic guidance and constant encouragement in completing the project.

We extend our thanks to our Project Coordinator **Dr. A. RAJALAKSHMI**, Professor, Department of Electrical and Electronics Engineering, for her cooperation.

We express our sincere thanks to **Dr.C.KAMALAKANNAN**, Professor and Head of the Department for his guidance and encouragement during this project.

We express our sincere thanks to **Dr. S. RAMAREDDY**, Professor and Dean, Department of Electrical and Electronics Engineering, for his guidance and Encouragement during this project.

We also express our thankfulness to **Dr.M.SUBBIAH**, Emeritus Professor of Department of Electrical and Electronics Engineering, for his guidance and support during this project .

We express our thankfulness to **Dr.S.N.MURUGESAN,** Principal, Rajalakshmi Engineering College, and the management for their kind support and the facilities provided to complete our work in time.

We also express our gratefulness to our parents and classmates for their moral support and valuable suggestion during the course of the project.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLE

CHAPTER 1

INTRODUCTION

1.1 GENERAL

MOSFET is known as the Metal-Oxide-Silicon Field- Effect Transistor. The MOSFET is a form of insulated-gate field effect transistor that is created by the controlled oxidation of a semiconductor, often silicon. Because the device is available in very small sizes, a MOSFET can be either a core or an integrated circuit, in which case it is developed and produced on a single silicon chip. Because of the development of the MOSFET device, the field of switching in electronics has undergone a significant transformation. Let us now proceed to a more in-depth examination of this topic.

The massive usage of the fossil fuels, such as oil, coal and gas, result in global surface temperature increase and serious CO_2 gas emission, which worsens human environment. On the other hand, the world proved reserves of theoil, coal and natural gas could not satisfy. Because of the requirement of electricsupply is increasing day by day, so they have been increased gaining popularity for integration of renewable energy resources. The renewable energy resources are efficient, not harmful, non-hazardous and environmentally friendly performance. These converters are widely used in applications such as DC distribution systems, DC micro grids, solid-state transformer and grid-tied invertersystems. The output voltage produced by renewable sources like solar panels, fuel cells, wind mills, etc., in range of 20V to 45V. To boost that low output voltage, they are using high voltage gain converters. These high voltage DC-DC converters make it feasible for connecting such sources to the high voltage bus by boosting the low voltage from the sources to higher voltage.

The employment of SiC MOSFETs enables the operation of converter at higher switching frequencies, significantly reducing the inductive and capacitive filter values.

The switching frequency of the proposed converter is 250 kHz. The peak-current mode control (PCMC) is employed for ensuring the load voltage regulation under steady state and for mitigating the effects of source and load transients. The 200W protype for 24V to 28V step up operation has been developed to validate the proposed system.

1.2 LITERATURE SURVEY

- BHARATHI SANKAR has published Analysis and Development of SiC MOSFET BOOST CONVERTER AS SOLAR PV PRE-REGULATOR In This paper, Renewable energy source such as photovoltaic (PV) cell generates power from the sun light by converting solar power to electrical power with no moving parts and less maintenance. A single photovoltaic cell produces voltage of low level. In order to boost up the voltage, a DC-DC boost converter is used. In order to use this DC-DC converter for high voltage and high frequency applications, Silicon Carbide (SiC) device is most preferred because of larger current carrying capability, higher voltage blocking capability, high operating temperature and less static and dynamic losses than the traditional silicon (Si) power switches. In the proposed work, the static and dynamic characteristics of SiC MOSFET for different temperatures are observed.

- ALBERTO RODRIGUEZ AND FERNANDO BRIZ has published SiC AND SIC TRANSISTORS COMPARISON IN BOOST CONVERTER In this Paper, Development of new wide band gap (WBG) power devices, and among them, of Silicon Carbide (SiC) power devices, has been an active field of research during the last years. Potential advantages SiC devices over their Si counterparts include a significantly higher breakdown field, higher operating temperatures as well as higher switching frequencies. However, manufacturing of SiC power devices is not a mature technology yet, their performance being far from their potential limits. A comparison between SiC and Silicon (Si) power devices is presented in this paper. Three different power devices are analysis of with the aim of verifying the theoretical improvement in the performance of SiC over Si transistors: SiC JFET, SiC MOSFET and Si IGBT.

- **HAIDER ZAMAN AND HUSAN ALI** has published **SILICON-CARBIDE MOSFET BASED SYNCHRONOUS DC/DC BOOST CONVERTER** In this Paper, The Silicon-Carbide (SiC) MOSFET belongs to the family of wide-bandgap devices and has the inherit property of lower switching and conduction losses as compared to the silicon counter part. The employment of SiC MOSFETs enables the operation of converter at higher switching frequencies, significantly reducing the inductive and capacitive filter values. The switching frequency of the proposed converter is 250kHz. The peak-current mode control (PCMC) is employed for ensuring the load voltage regulation under steady state and for mitigating the effects of source and load transients. The 200W protype for 24V to 28V step up operation has been developed to validate the proposed system. The results in steady state and transient state are presented which depicts the satisfactory performance of the proposed converter.

- Mutthi Karunanidhi has published the Design and execution of Quadratic Boost Converter (QBC) in Renewable Energy Synergies. In this paper, the output voltage of the renewable energy sources such as solar is very low which is not sufficient to drive the loads in practical. To increase the voltage level, there are various boost converter configurations available in the literature. Thesignificant structure is the quadratic boost converter which has so many advantages than the conventional converters. In this paper, novel quadratic boost converter is proposed and implemented in hardware prototype and the experimental results are compared with the designed values**.**

1.3 SUMMARY OF LITERATURE SURVEY

From this literature survey the following points are observed:

- The performance parameters of the proposed converter such as output voltage ripple input current ripple and losses are computed and it is compared with the classical silicon (Si) MOSFET converter.

- Three different power devices are analyzed, with the aim of verifying the theoretical improvement in the performance of SiC over Si transistors: SiC JFET, SiC MOSFET and Si IGBT. A boost DC to DC converter topology will be used for this purpose

- The employment of SiC MOSFETs enables the operation of converter at higher switching frequencies, significantly reducing the inductive and capacitive filter values. The switching frequency of the proposed converter is 250 kHz.

1.4 OBJECTIVE

- To design, simulate and implement a boost converter with high duty ratio using a SiC MOSFET and compare the performance of the converter with equivalent Si MOSFET.

1.5 ORGANIZATION OF THESIS

This thesis is organized into five chapters. The description about each chapter is as follows:

- **Chapter 1** deals with introduction, literature survey, summary of literature survey and chapter wise organization.
- **Chapter 2** deals with block diagram & explanation, circuit diagram, design and analysis of Si MOSFET based boost converter.
- **Chapter 3** deals with simulation of boost converter in open loop mode using SiC MOSFET and Si MOSFET and performance of the converter is evaluated.
- **Chapter 4** deals with hardware components description, hardware working & result.
- **Chapter 5** deals with conclusion, and scope of future works.

CHAPTER 2

DESIGN OF Si BASED BOOST CONVERTER

2.1 INTRODUCTION

Increasing use of renewable energy sources and its applications has increased the need of high voltage gain converters. The more efficient the design of system is the more output would be achieved. Because of the requirement of electric supply is increasing day by day, so they have been increased gaining popularity for integration of renewable energy resources. The renewable energy resources are efficient, not harmful, non-hazardous and environmentally friendly performance.

These converters are widely used in applications such as DC distribution systems, DC micro grids, solid-state transformer and grid-tied invertersystems. The output voltage produced by renewable sources like solar panels, fuel cells, wind mills, etc., in range of 20V to 45V. To boost that low output voltage, they are using high voltage gain converters. These high voltage DC-DC converters make it feasible for connecting such sources to the high voltage bus by boosting the low voltage from the sources to higher voltage. So this boost converter will be used as a good source of Energy for the system.

2.2 BLOCK DIAGRAM

A boost converter block diagram shown in fig 2.1 consists of four blocks namely: Input voltage source, boost converter, load and PWM pulses.

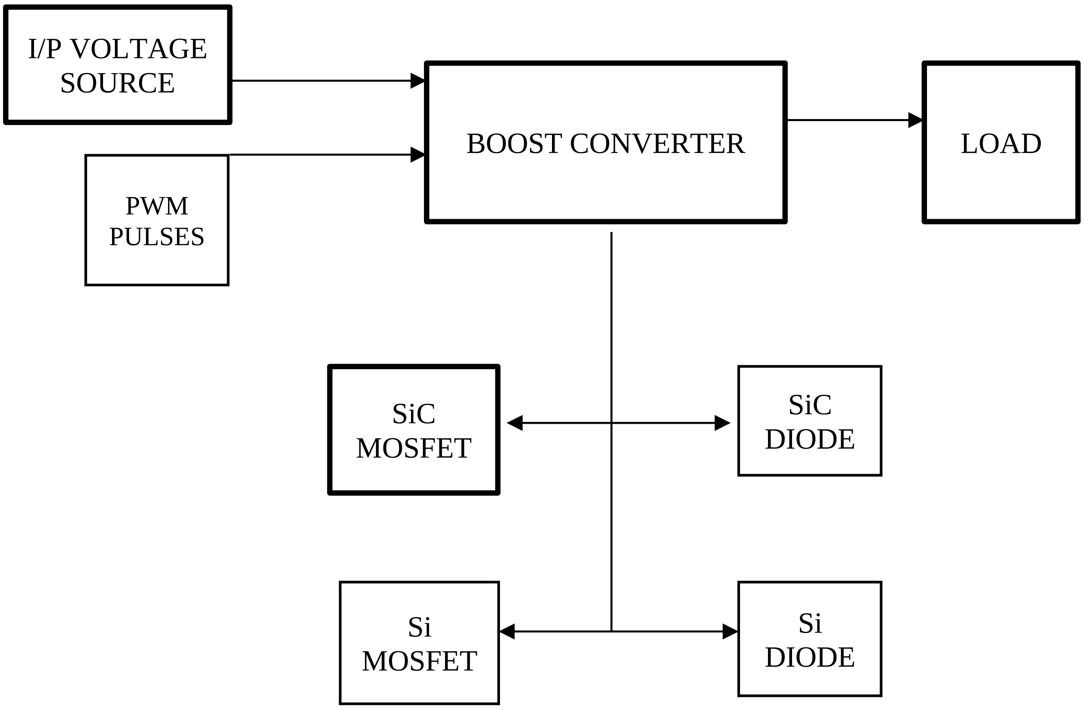

Figure 2.1 Block Diagram of Boost Converter

DC INPUT**:** The inputs provide a voltage of 20V (typically voltage range of solar panels) and are connected in a shunt combination.

BOOST CONVERTER**:** The boost converter is used to "step-up" an input voltage to some higher level, required by a load. This offers a relatively high voltage gain for a simple converter.

LOAD**:** The device which takes electrical energy is known as the electrical load. The electrical load may be resistive, inductive, capacitive or some combination between them.

SiC MOSFET**:** SiC MOSFETs exhibit higher blocking voltage, lower on state resistance and higher thermal conductivity than their silicon counterparts. SiC MOSFETs are designed and essentially processed the same way as silicon MOSFETs.

PWM PULSE**:** Pulse width modulation, or pulse duration modulation, is a method of reducing the average power delivered by an electrical signal, by effectively chopping it up to discrete parts.

2.3 BOOST CONVERTER SPECIFICATIONS

Ripple in the output Voltage = 1 % of output Voltage

Ripple in the inductor current = 15% of Input Current

Input Voltage (V_{in}) = 20V,

Output voltage (V_{out}) = 800V,

Switching Frequency (f_s) = 100 kHz

2.4 BOOST CONVERTER DESIGN

In this section, boost converter design such as duty ratio, inductor, capacitor and load are discussed.

2.4.1 DUTY RATIO ESTIMATION

For the input voltage V_{in} = 20 V and for the desired output voltage of 800 V,

$$\frac{V_0}{V_{in}} = \frac{1}{1-D} \tag{2.1}$$

$$V_0 = \left(\frac{1}{1-D}\right) V_{in}$$

$$800 = \left(\frac{1}{1-D}\right) 20$$

$$\frac{1}{1-D} = 40$$

$$\frac{1}{40} = 1 - D$$

$$0.025 = 1 - D$$

$$D = 1 - 0.025$$

$$D = 0.975$$

Therefore, the duty ratio will be 0.97

2.4.2 RESISTIVE LOAD CALCULATION

This section discuss the load calculation, by assuming lossless converter.

2.4.3 Output Current I_0

$$P_0 = V_0(I_0) \quad (2.2)$$

$$100 = 800(I_0)$$

$$I_0 = 1/8$$

$$I_0 = 0.125\text{A}$$

$$= 125\text{mA}$$

Assume the loss less converter, so P_o equal to P_{in}

$$P_0 = V_{in}\,(I_{in}) \quad (2.3)$$

$$100 = 20(I_{in})$$

$$I_{in} = 100/20$$

$$= 5\text{A}$$

For resistance R,

$$I_0{}^2\text{R} = 100$$

$$\text{R} = 100\,/(0.125)^2$$

$$= 6400 \text{ or } 6.4\text{k}\Omega$$

2.4.4 Inductor Design

This section describes the inductor value calculation, by assuming the inductor ripple current equal to 15% of input current.

Inductor ripple current ΔI_L = 15% of input current

$$= \frac{15}{100} * 5$$

$$= 0.75\text{A}$$

$$\Delta I_L = \frac{V_S\,D}{fsL} \quad (2.4)$$

$$0.75 = \frac{V_S\,D}{fsL}$$

$$0.75 = \frac{20\ (0.975)}{100 * 10^3 * L}$$

$$L = \frac{20\ (0.975)}{100 * 10^3 * 0.75}$$

$$L = 0.26 * 10^{-3}$$

$$L = 260\mu H$$

2.4.5 Capacitor Design

This section describes the capacitor value design by assuming 1% of ripple in the output voltage.

Ripple in the output capacitor voltage ΔV_c 1% of output voltage

$$\Delta V_c = 1/100 * 800$$

$$= 8V$$

$$\Delta V_c = \frac{I_a D}{F_s C} \tag{2.5}$$

$$8 = \frac{(0.125)*(0.975)}{100*10^3 * C}$$

$$C = \frac{(0.125)*(0.975)}{100*10^3 * 8}$$

$$C = 0.15uf$$

2.5 SIMULATION CIRCUIT DIAGRAM

LTSpice is a spice based analog electronic circuit simulator computer software, produced by semiconductor manufacturer analog devices which allows you to draft, probe and analyze the performance of your circuit design.

2.5.1 SI BASED BOOST CONVERTER

LTSpice simulation software is used to simulate the boost converter with Si MOSFET of 800V breakdown voltage and Si diode of 800V reverse recovery voltage for simulation. The simulation circuit diagram with all the designed parameters is shown in the figure 2.2.

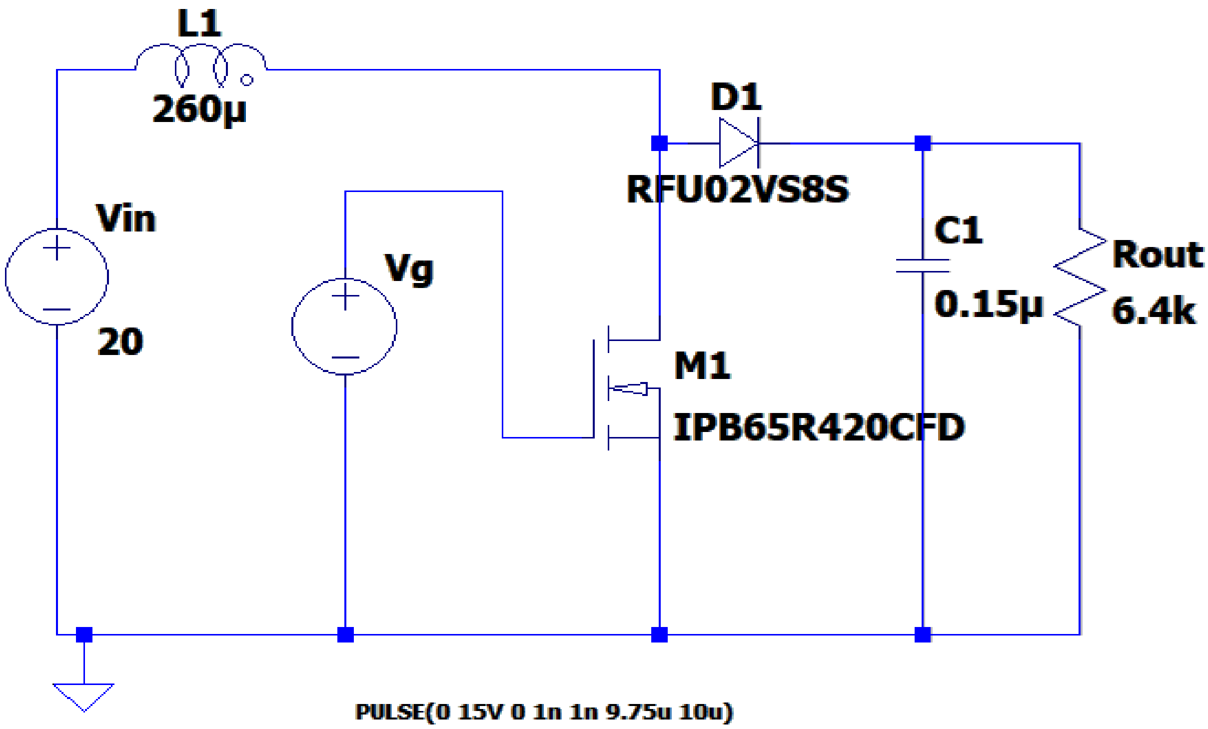

Figure 2.2 Simulation Circuit Diagram of Si based Boost Converter

2.6 SIMULATION OUTPUTS

This section investigates the simulated waveform such as input voltage, output voltage, output voltage ripple, inductor current ripple and MOSFET voltage and current stress.

2.6.1 INPUT VOLTAGE WAVEFORM

For Si MOSFET based boost converter, the input voltage at steady state condition is 20V and it is shown in the figure 2.3.

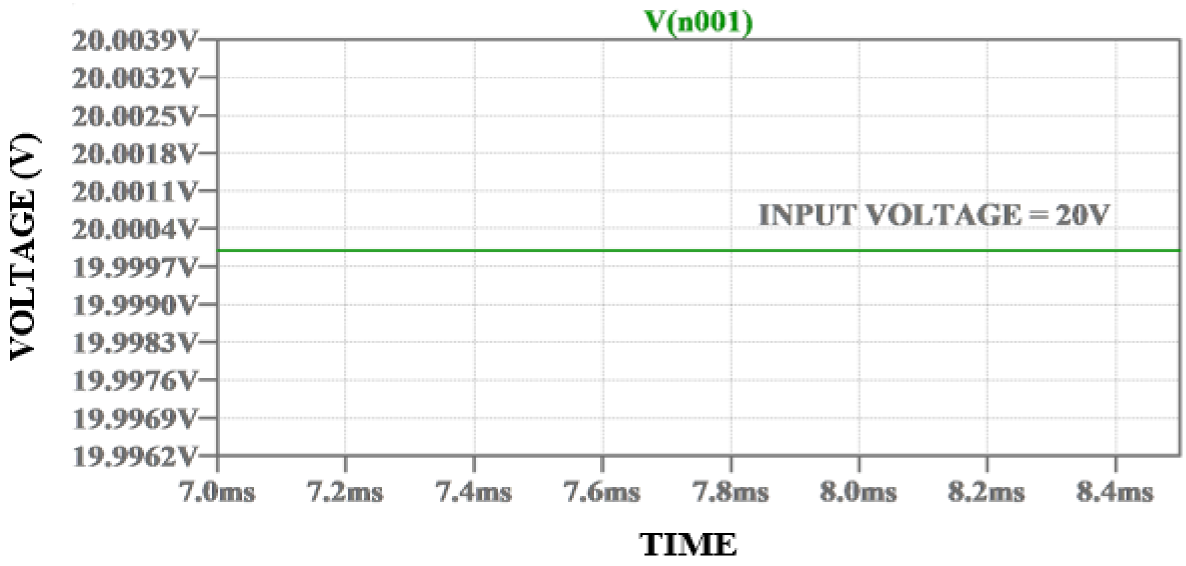

Figure 2.3 Input waveform of Si based boost converter

2.6.2 OUTPUT WAVEFORM

For SiC MOSFET based boost converter, for the given input voltage of 20V the boosted output voltage at the steady state is equal to 730.25V and it is shown in the figure 2.4

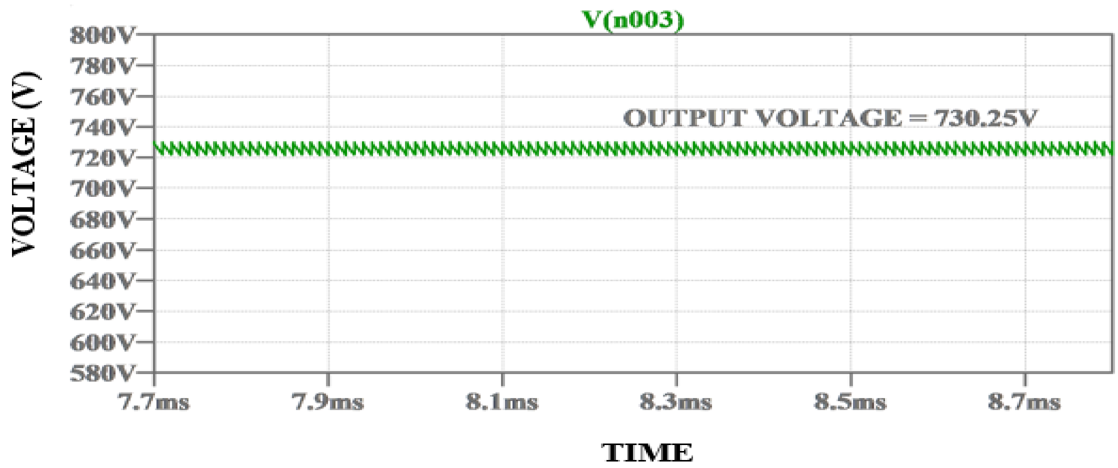

Figure 2.4 Output Waveform of Si based boost converter

2.6.3 OUTPUT RIPPLE VOLTAGE

This section describes the ripple voltage and ripple factor calculation from the figure 2.4.

Maximum voltage $V_o$max = 730.21V

Minimum voltage $V_o$min =721.12V

From the values of $V_o$max and $V_o$min we need to find peak to peak ripple voltage

$$= V_o\text{max} - V_o\text{min} \tag{2.6}$$

$$= 730.21 – 721.12$$

$$= 8.49\text{V}$$

From the peak to peak ripple voltage calculated ripple factor of the output voltage is,

$$\text{Ripple factor} = \frac{Peak\ to\ peak\ ripple\ Voltage}{Average\ Voltage} \tag{2.7}$$

$$= \frac{8.49}{725.4}$$

$$= 1.17\%$$

2.6.4 INDUCTOR RIPPLE CURRENT

This section describes the inductor ripple current calculation using the figure 2.5.

The $I_L$max = 5.814A and $I_L$min = 5.135A

From $I_L$max and $I_L$min peak to peak inductor ripple current can be calculated as

$$= I_L\text{max} - I_L\text{min} \tag{2.8}$$

$$=5.814\text{A} – 5.135\text{A}$$

$$=0.679\text{A}$$

The average inductor current found form the inductor ripple current waveform is equal to 5.472A

$$\text{Ripple factor} = \frac{Peak\ to\ peak\ inductor\ ripple\ current}{average\ current} \tag{2.9}$$

$$= \frac{0.679}{5.472}$$

Ripple factor = 12.4%

Inductor peak to peak ripple current at steady state is shown in the fig 2.5 from the figure, the maximum ripple current is 5.81A and minimum ripple current is 5.11A and peak to peak ripple current is 0.679A.

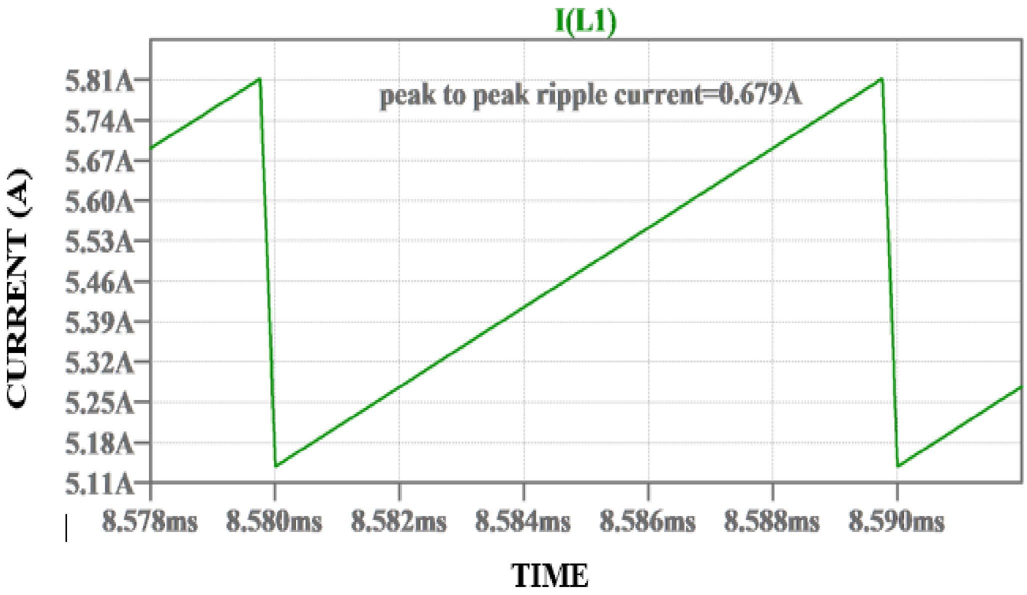

Figure 2.5 peak to peak inductor ripple current

2.6.5 CAPACITOR RIPPLE VOLTAGE

Capacitor output voltage ripple is shown in the fig 2.6 from the steady state waveform it is inferred that the peak to peak ripple voltage is equal is 8.49V

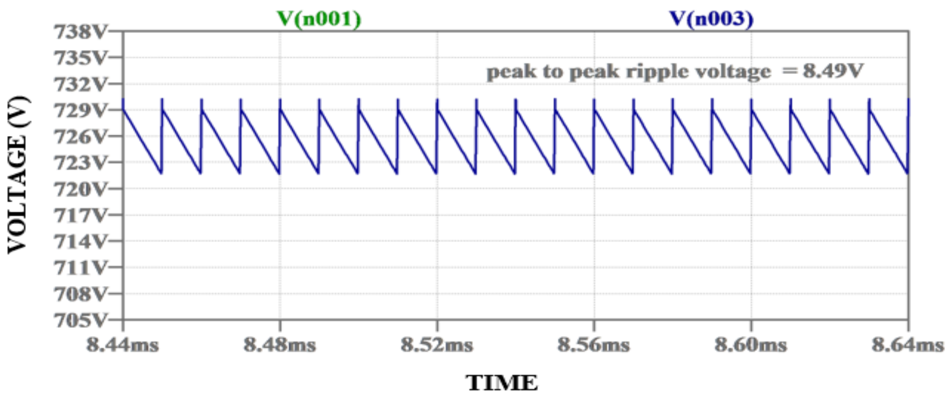

Figure 2.6 Capacitor Ripple voltage

From the above capacitor voltage waveform

The $V_C$max = 730.26V and $V_C$min = 721.67V

From $V_C$max and $V_C$min peak to peak ripple voltage is calculated as

Peak to peak ripple voltage

$$= V_C\text{max} - V_C\text{min} \tag{2.10}$$

=730.26V – 721.67V

=8.49V

The average voltage found from the capacitor ripple voltage waveform is equal to 725.41V.

2.6.6 MOSFET CURRENT AND VOLTAGE STRESS

This section investigates the voltage and current stress of the Si MOSFET based boost converter at steady state with switching frequency equal to 100 kHz.

2.6.7 DRAIN CURRENT (I_D)

Drain current of the Si MOSFET at steady state is shown in the fig 2.7. From the steady state waveform the peak current in the diode is approximately equal to 7A.

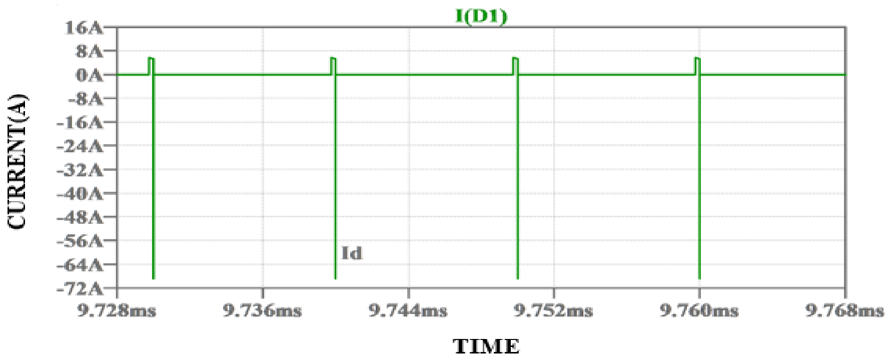

Figure 2.7 Drain current waveform

2.6.7 DRAIN SOURCE VOLTAGE (V_{DS})

Drain source voltage waveform at steady state condition is shown in the fig 2.8

From the steady state waveform the peak voltage is 730V.

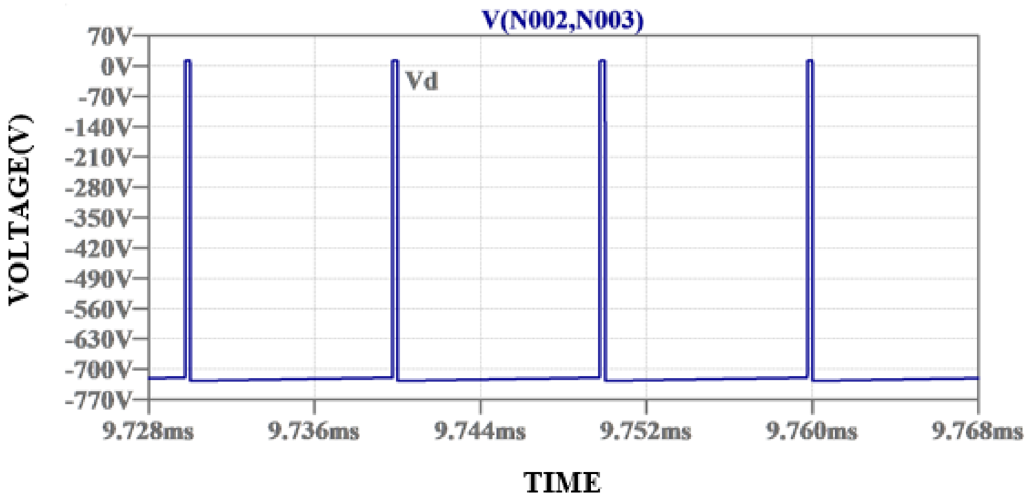

Figure 2.8 Voltage waveform Drain Source

2.7 DIODE CURRENT AND VOLTAGE STRESS

Si MOSFET based boost converter, the stress occurred in the diode during Turn - ON and Turn - OFF condition is discussed in this section.

2.7.1 DIODE CURRENT (I_{D1})

Diode current waveform during turn ON instant at steady state condition is shown in the fig 2.9

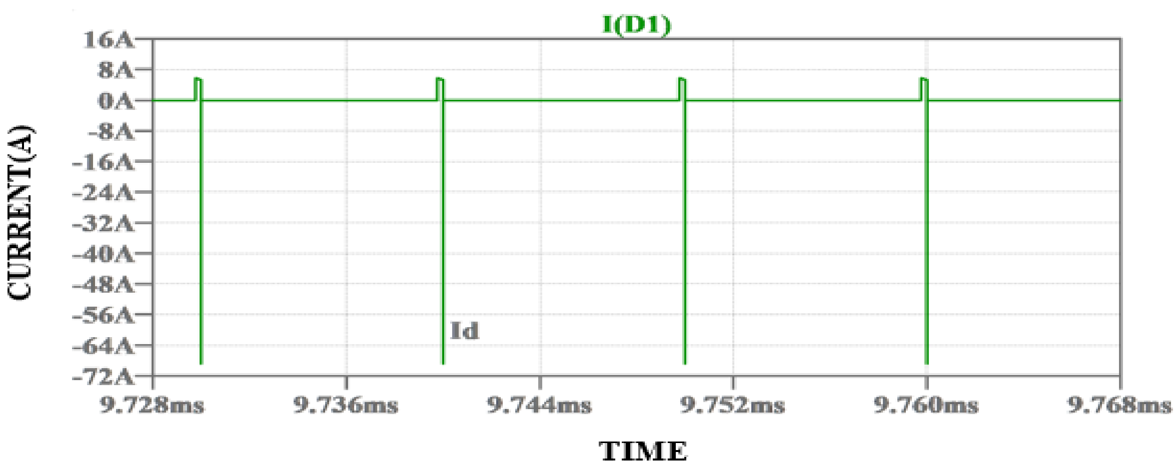

Figure 2.9 Diode Current Waveform

2.7.2 DIODE VOLTAGE (V_D)

Reverse voltage is the maximum voltage that a diode can withstand in the reverse direction without breaking down or avalanching. The value of the diode voltage is observed from the fig 2.10 It is observed that the peak reverse voltage is approximately equal to 720V.

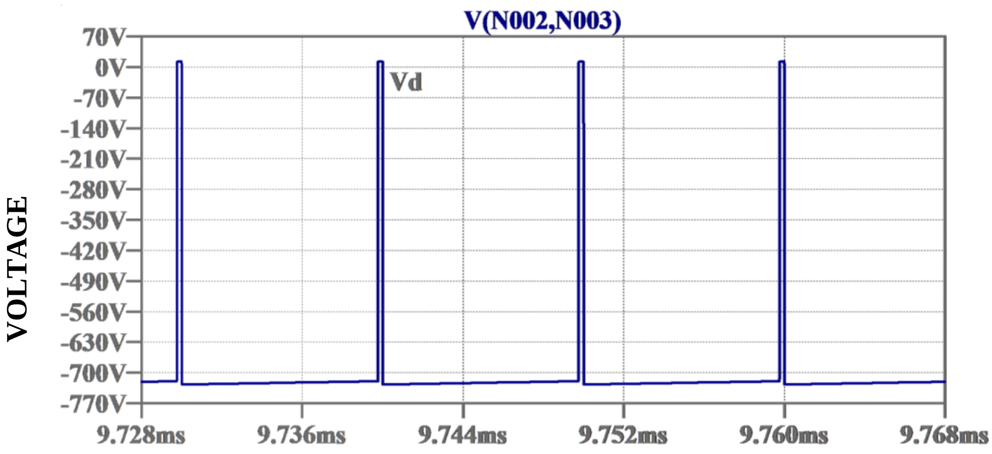

Figure 2.10 Diode voltage

TIME

2.8 INPUT AND OUTPUT POWER

The input power and output power at steady state is measured from the fig 2.11 and fig 2.12 At s teady state the input power is approximately equal to 109.51W and output power is equal to 82.22W.

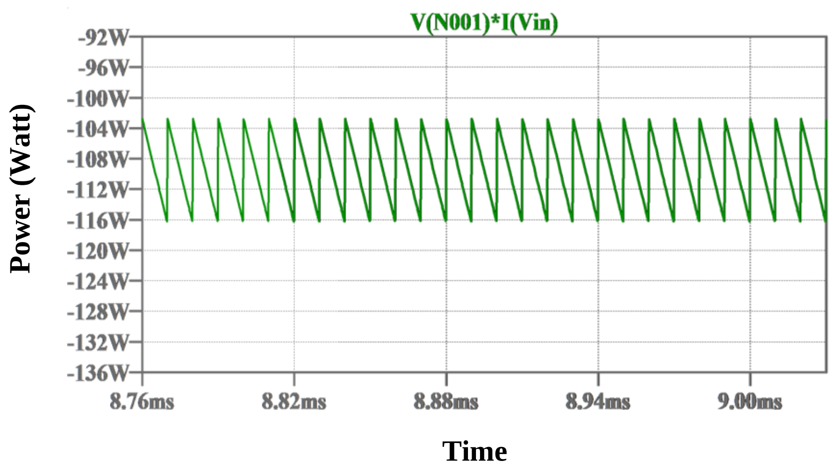

Figure 2.11 Input power

The output power (P_{out}) obtained from the below waveform is shown in fig 2.12

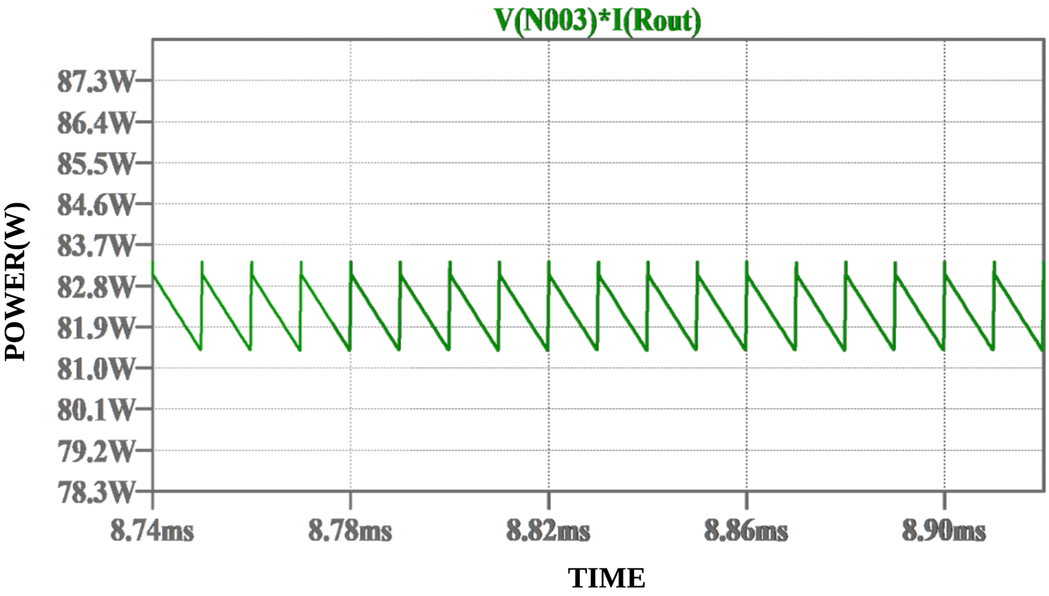

Figure 2.12 Output power

2.9 LOSSES DISSIPATED

From the obtained values of the input power and output power, efficiency and power loss calculation is discussed in this section.

Total losses = $P_{in} - P_{out}$

=109.51 – 82.22

= 27.29W

The Total losses dissipated in the converter is the addition of diode loss and MOSFET losses.

Diode loss obtained from the simulation circuit is 3.628W.

Losses in the MOSFET conduction and switching loss.

MOSFET loss = MOSFET conduction + MOSFET switching loss

MOSFET power loss = $(I_{DS})^2(R_{DS} - ON)$

= $(5.08)^2(0.378)$

= 9.75W

Total losses = Diode loss + MOSFET loss

= 3.628 + 23.202w

Total losses = 27.29W

2.10 EFFICIENCY

From the obtained input and output power efficiency of the Si based boost converter is

$$\text{Efficiency} = \frac{P_o}{Pin}$$

$$= \frac{82.22}{109.51}$$

Efficiency = 75%

CHAPTER 3

SiC MOSFET BASED BOOST CONVERTER

SIMULATION CIRCUIT DIAGRAM

LTSpice Simulation software is used to simulate the boost converter with SiC MOSFET of 800V breakover voltage and SiC diode of 800V reverse recovery voltage chosen and the simulation circuit diagram with all the designed parameter included in the circuit are shown in the below figure 3.1.

3.1 SiC BASED BOOST CONVERTER

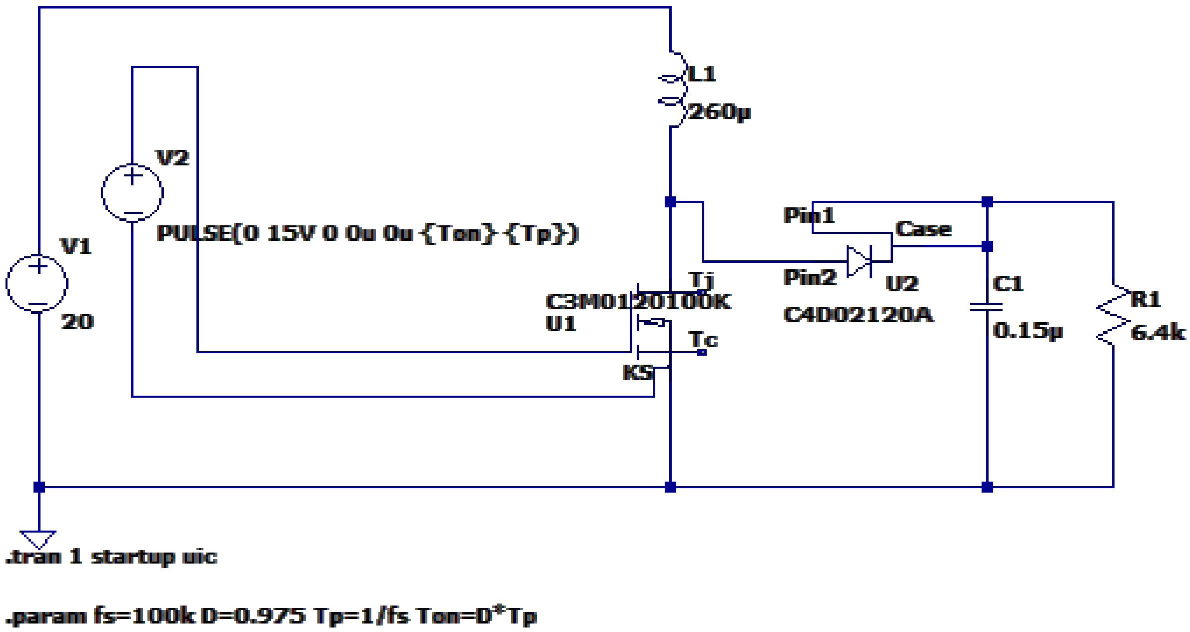

Figure 3.1 Simulation circuit Diagram of SiC based boost converter

3.2 INPUT VOLTAGE WAVEFORM

For SiC MOSFET based boost converter, the input voltage at steady state condition is 20 V and it is shown in the figure 3.2.

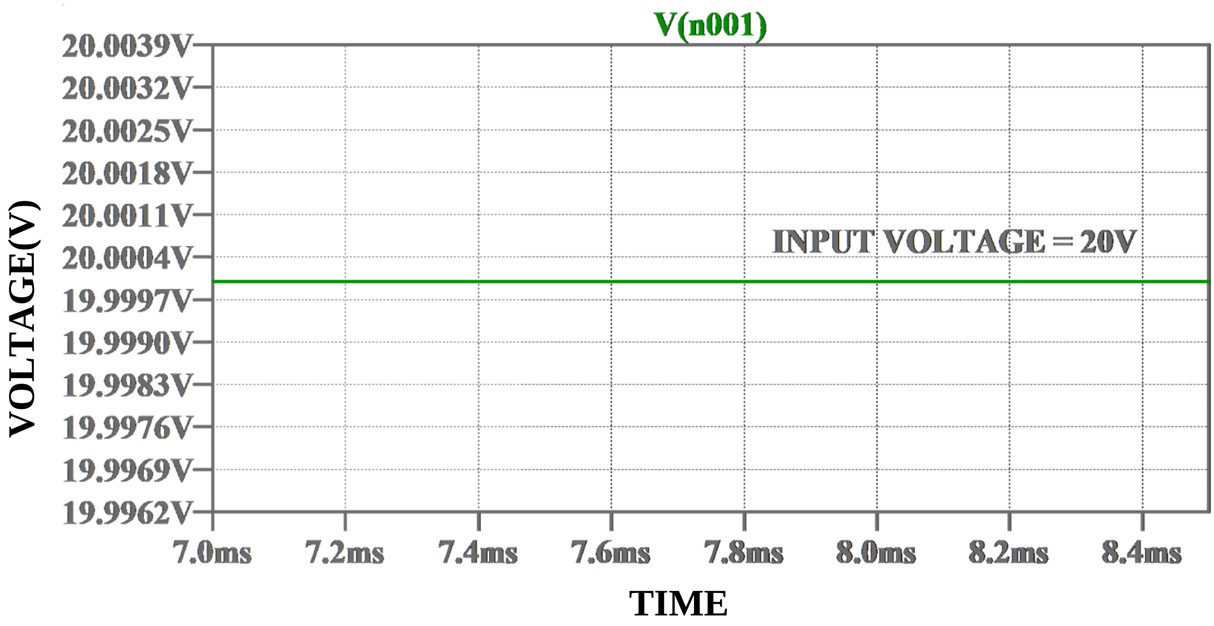

Figure 3.2 Input waveform of SiC based boost converter

3.3 OUTPUT VOLTAGE WAVEFORM

For SiC MOSFET based boost converter, for the given input voltage of 20V the boosted output voltage at the steady state is equal to 815.25V and it is shown in the figure 3.3.

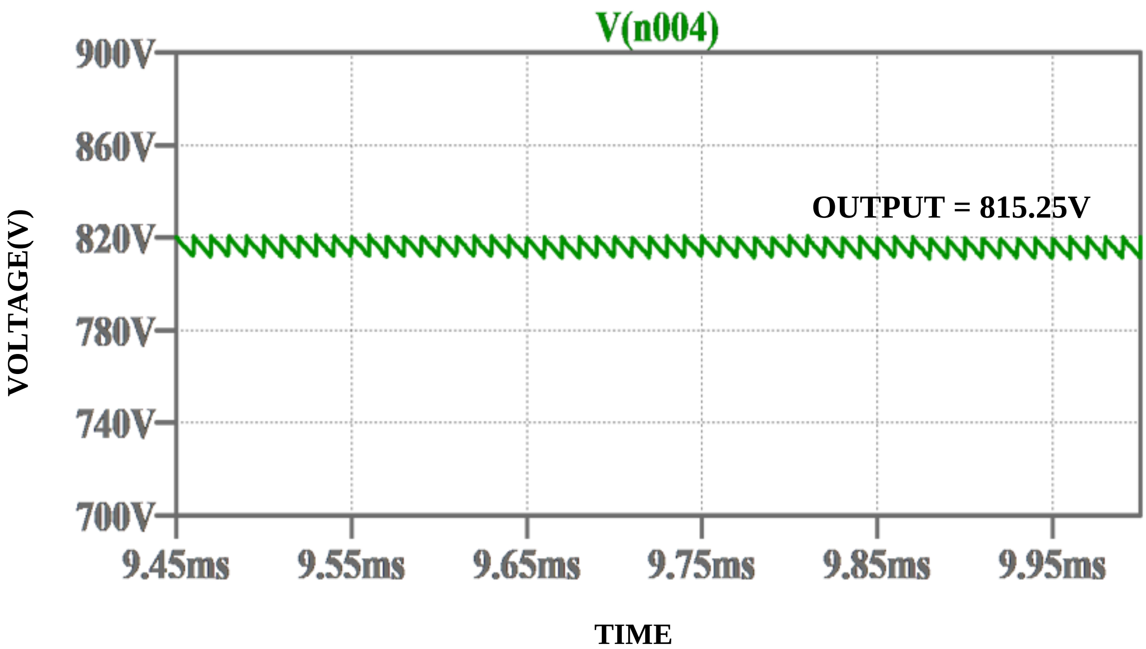

Figure 3.3 Output waveform of SiC based boost converter

3.4 OUTPUT RIPPLE VOLTAGE

This section describes the performance parameters of the DC – DC Converter such as ripple voltage and ripple factor from the output voltage waveform. The ripple in the output voltage can be calculated from the figure 3.3. The maximum voltage $V_O$max=820.7V. The minimum voltage $V_O$min=812.0V.

From the values of $V_O$max and $V_O$min the peak to peak ripple voltage is

$=V_O$max-$V_O$min

= 820.7V-812.0V

=8.7V

From the peak-to-peak ripple voltage the ripple factor of the output voltage is

$$\text{Ripple factor} = \frac{peak\ to\ peak\ ripple\ voltage}{average\ voltage}$$

$$= \frac{8.7}{812.0}$$

= 1.06%

3.5 INDUCTOR RIPPLE CURRENT

Inductor peak to peak ripple current at steady state is shown in the fig 3.4. From the fig, the maximum ripple current is 6.073A and minimum ripple current is 5.34A and peak to peak ripple current is 0.733A

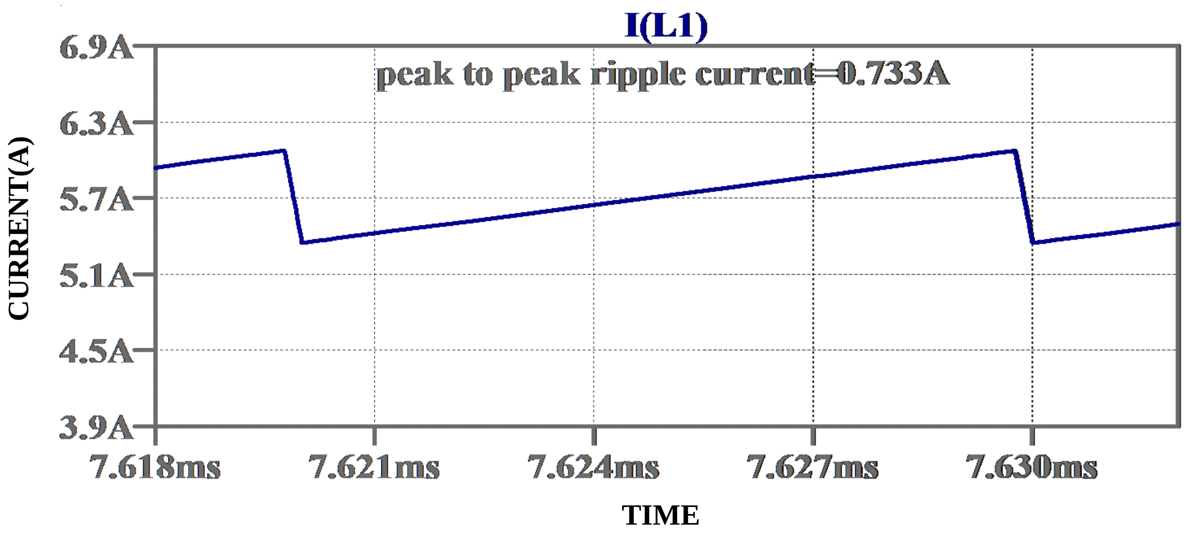

Figure 3.4 Inductor ripple current

From the above inductor current waveform

The $I_L$max = 6.073A and $I_L$min = 5.34A

From $I_L$max and $I_L$min peak to peak ripple current can be calculated

Peak to peak ripple current

$= I_L\text{max} - I_L\text{min}$

= 6.073A – 5.34A

= 0.733A

From the peak-to-peak ripple current the ripple factor can be calculated

The average current found form the inductor ripple current waveform is 5.71A

$$= \frac{peak\ to\ peak\ ripple\ current}{average\ current}$$

$$= \frac{o.733}{5.71}$$

Ripple factor = 12.8%

3.6 CAPACITOR RIPPLE VOLTAGE

Capacitor output voltage ripple is shown in the figure 3.5. From the steady state waveform, it is inferred that the peak to peak ripple voltage is equal is 8.61V.

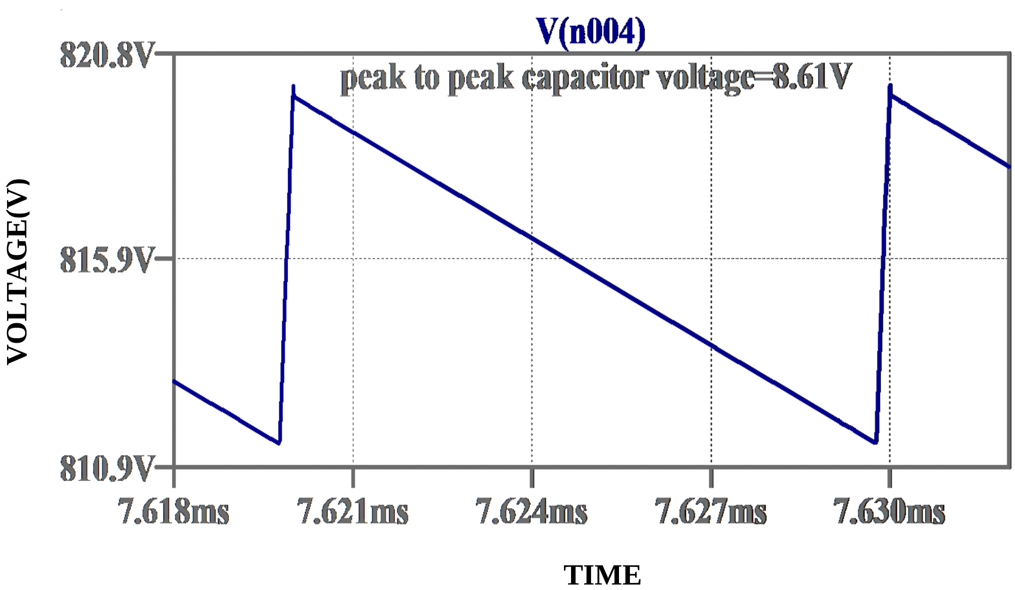

Figure 3.5 Capacitor Ripple voltage

From the above capacitor voltage waveform

$V_C$max = 820.06 V and $V_C$min = 811.45 V

From $V_C$max and $V_C$min peak to peak ripple voltage can be calculated

Peak to peak ripple voltage

= $V_C$max - $V_C$min

= 820.06V – 811.454V

= 8.61V

The average voltage found form the capacitor ripple voltage waveform is 815.66V.

3.7 MOSFET CURRENT AND VOLTAGE STRESS

This section investigates the voltage and current stress of the SiC MOSFET based boost converter at steady state with switching frequency equal to 100 KHZ.

3.7.1 DRAIN CURRENT (I_D)

Drain Current of the SiC MOSFET at steady state is shown in the figure 3.6. From the steady state waveform the peak current in the MOSFET is approximately equal to 8A.

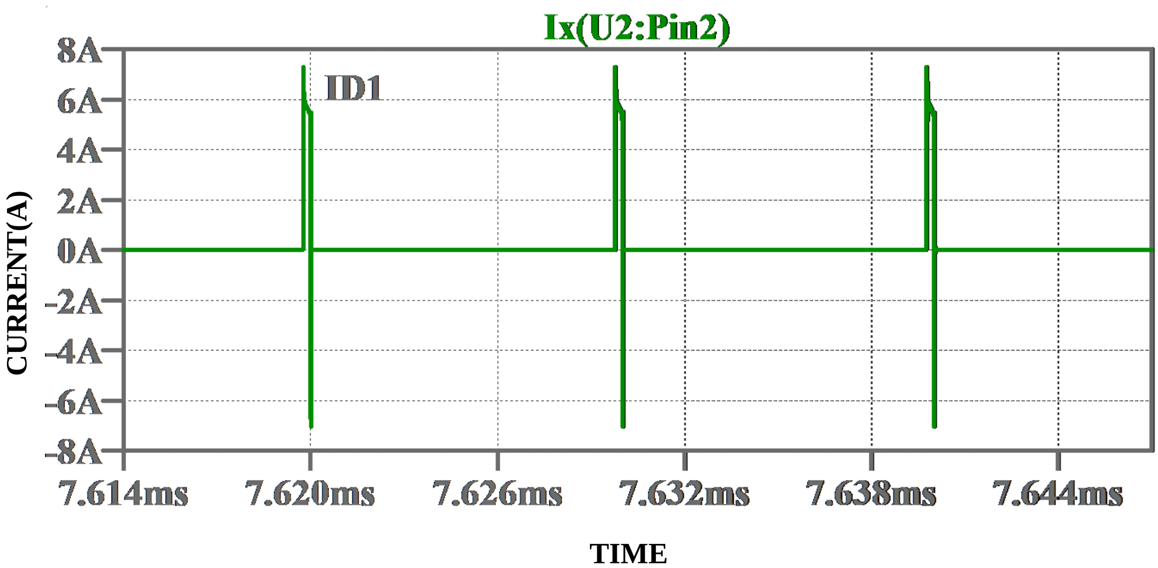

Figure 3.6 Drain Current waveform

3.7.2 VOLTAGE DRAIN SOURCE (V_{DS})

Drain source voltage waveform during turn – ON and turn – OFF instant is shown in the figure 3.7

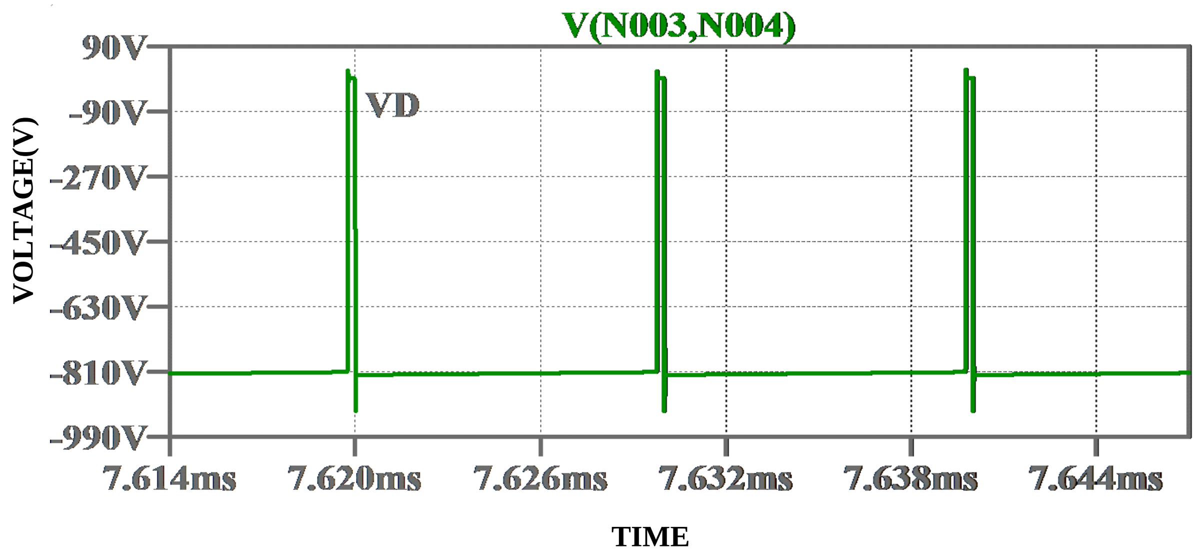

Figure 3.7 Drain Voltage waveform

3.8 DIODE CURRENT AND VOLTAGE STRESS

SiC MOSFET based boost converter, voltage and current stress occurred in the diode during turn - ON and turn - OFF condition is discussed in this section.

3.8.1 DIODE CURRENT (I_{D1})

Diode current waveform during turn- ON instant at steady state condition is shown in the figure 3.8.

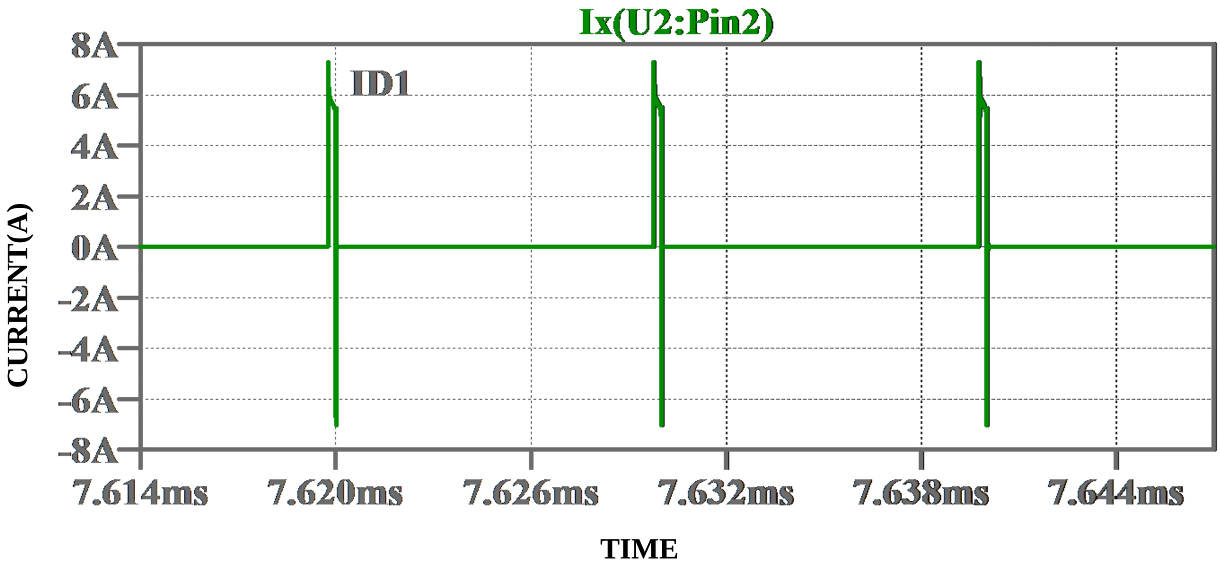

Figure 3.8 Diode current waveform

3.8.2 DIODE VOLTAGE (V_D)

The value of the diode voltage is observed from the figure 3.8 It is observed that the peak reverse voltage is approximately equal to 810V.

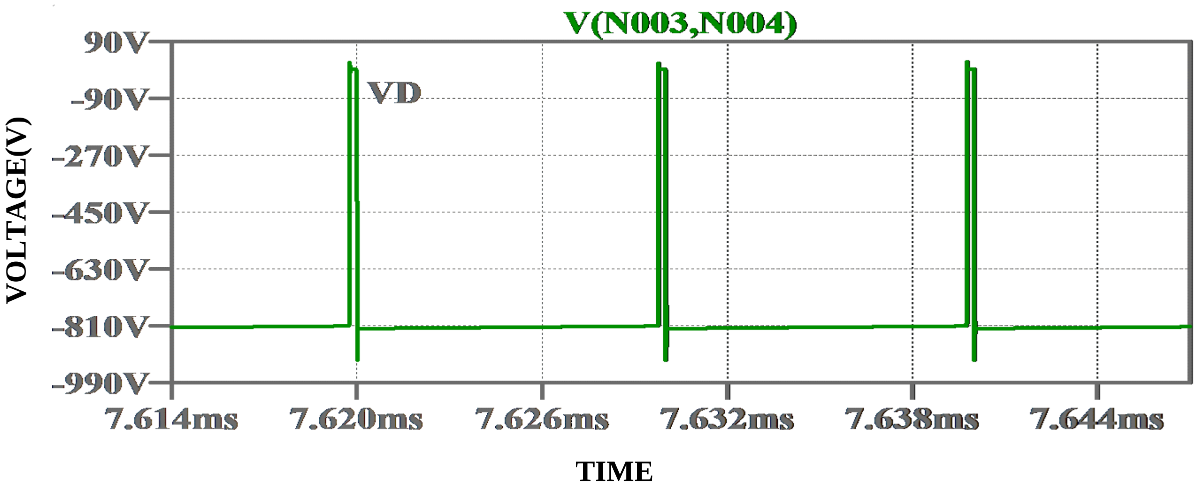

Figure 3.9 Diode Voltage

3.9 INPUT AND OUTPUT POWER

The input power and output power at steady state is measured from the figures 3.10 and 3.11. At steady state the input power is approximately equal to 114.14 W and output power is equal to 103.6W.

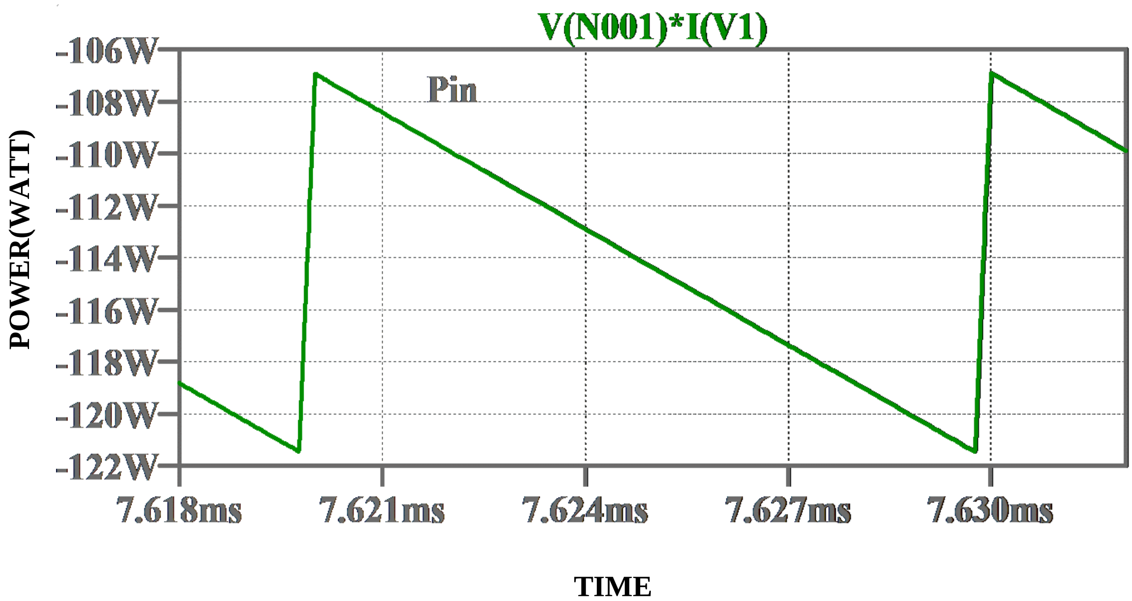

Figure 3.10 Input Power

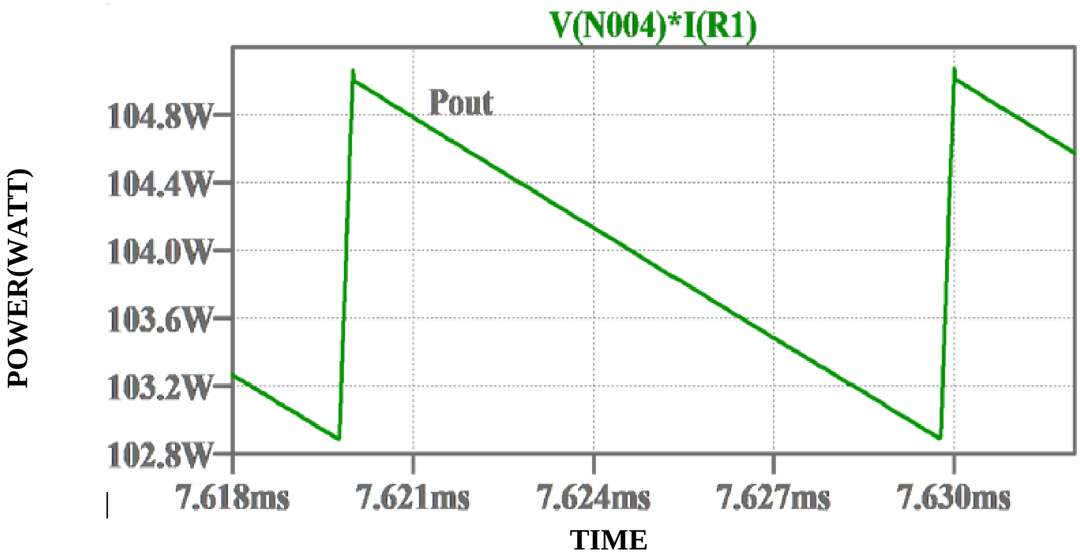

Figure 3.11 Output Power

3.10 LOSSES DISSIPATED

From the obtained values of the input and output power, efficiency and power loss calculation are discussed in this section.

Total losses = $P_{in} - P_{out}$

=114.14 – 103.9

= 10.24W

The total losses dissipated in the converter is the addition of diode loss and MOSFET loss.

Diode loss obtained from the simulation circuit is 2.46W

MOSFET loss is equal to conduction and switching loss

MOSFET loss = MOSFET conduction loss + MOSFET switching loss

MOSFET conduction losses = $(I_{DS})^2(R_{DS} - ON)$

= 13.45W

Total losses = Diode loss + MOSFET loss

= 2.46W + 9.9W

Total losses = 12.36W

From the obtained input power and output power, efficiency of the SiC based converter is equal to 91%.

PARAMETERS	Si MOSFET based boost converter	SiC MOSFET based boost converter
INPUT VOLTAGE	20V	20V
OUTPUT VOLTAGE	730.37V	815.25V
DUTY CYCLE	0.97	0.97
SWITCHING FREQUENCY	100KHz	100KHz
EFFICIENCY	75%	91%
INDUCTOR RIPPLE CURRENT	5.47A	5.71A
RIPPLE FACTOR	12.4%	12.8%
CAPACITOR RIPPLE VOLTAGE	725.41V	815.66V
DIODE LOSS	2.46W	3.628W
MOSFET CONDUCTION	23.70W	9.8W
MOSFET SWITCHING	13.45W	5.4W
TOTAL LOSS	27.29W	13.24W

Table 3.11 Comparison table of Si and SiC MOSFET Boost Converter

3.11 CONCLUSION

Thus the simulation output, of SiC MOSFET based boost converter, and the output waveform, efficiency and losses were discussed in this chapter. It is observed that the losses in the converter realized with the SiC devices is reduced and efficiency is improved.

CHAPTER 4

HARDWARE IMPLEMENTATION

4.1 INTRODUCTION

This chapter discusses the hardware components and implementation of the power converter circuit with all Si and SiC devices. Moreover, firing circuit components and generation of PWM pulses are also discussed in this chapter.

4.2 BLOCK DIAGRAM

The block diagram of the hardware implementation of the boost converter is shown in the figure 4.1. The hardware block diagram consists of five blocks, namely input voltage source, PWM pulse generation using microcontroller, driver circuit, boost converter and load. The active devices in the boost converter is realized with all-SiC and all- Si devices.

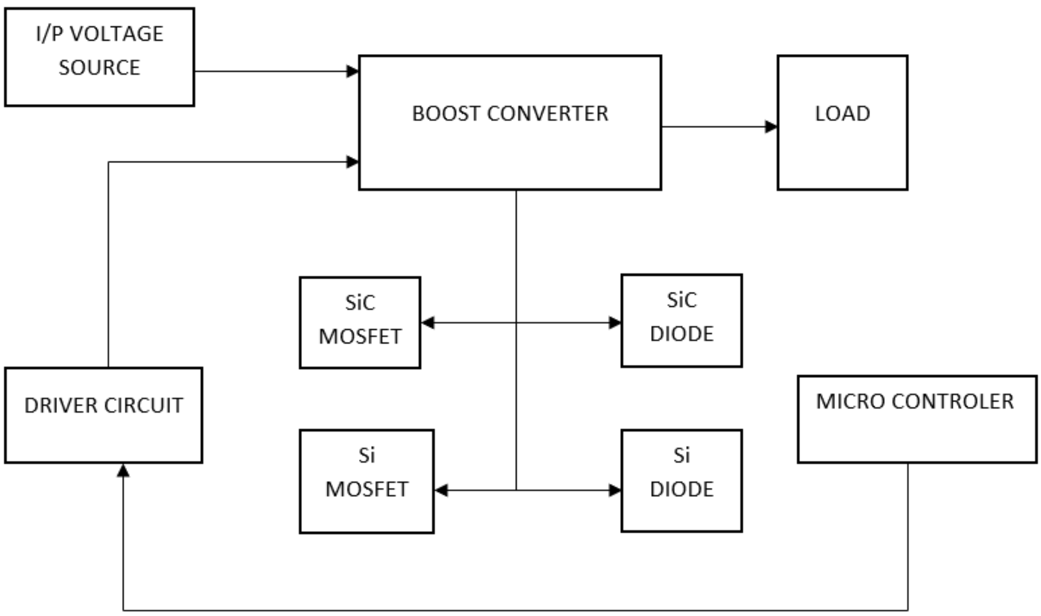

Figure 4.1 Hardware implementation block diagram of boost converter

4.3 HARDWARE CIRCUIT COMPONENTS

This section describes the hardware components used in the realization of the boost converter.

4.3.1 DC SUPPLY

Low voltage DC source can be used as input supply. During the hardware implementation of boost converter with SiC MOSFET at high duty ratio, we used dual RPS (Regulated Power Supply) for input voltage of 12 V to study the nature of working of the circuit. An RPS is an electronic circuit that provide a constant and stable DC input voltage for the boost converter. The fig 4.2 shows the front view diagram of RPS.

Fig. 4.2 Regulated Power Supply (RPS)

4.4 2SK3878 MOSFET

The 2SK3878 is a high power MOSFET (Metal-Oxide-Semiconductor Field-Effect Transistor) that is designed for use in high-speed switching applications. MOSFETs are semiconductor devices that can be used as electronic switches or amplifiers. The 2SK3878 is a N-channel MOSFET, meaning that it has a channel made of n-type semiconductor material. It has a maximum drain-source voltage (VDS) of 600 volts and a maximum continuous drain current (ID) of 8 amperes.

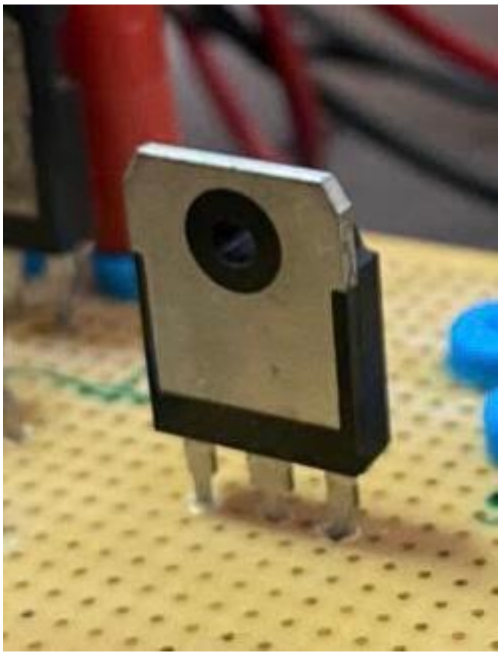

Fig 4.3 Diagram of 2SK38978 MOSFET

4.5 10A10 Diode

The 10A10 is a type of rectifier diode. Rectifier diodes are semiconductor devices that allow current to flow in only one direction, and are commonly used in power supply circuits to convert AC (alternating current) to DC (direct current).The 10A10 diode is rated for a maximum repetitive reverse voltage (VRRM) of 1000 volts and a maximum forward current (IF) of 10 amperes. It has a low forward voltage drop (VF) of around 1.1 volts at a forward current of 10 amperes, which means that it can efficiently convert AC to DC with minimal power loss.

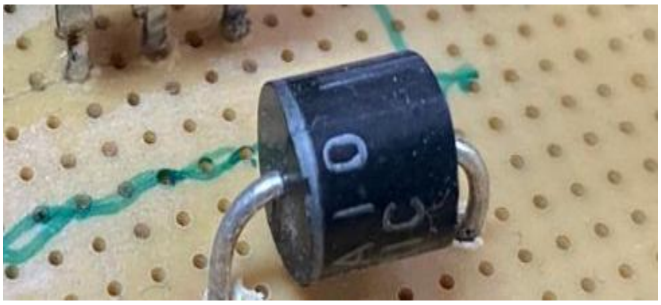

Fig. 4.4 10A10 diode

4.6 Resistor

A 10 K resistor is a resistor with a resistance value of 10 kilohms (kΩ), which means that it can limit or control the flow of electric current through a circuit to a certain degree. The colour code bands on a 10K resistor are typically brown, black, orange, and gold, which indicate the resistance value and tolerance of the resistor.

Fig 4.5 Resistor

4.7 Transformer

A transformer that provides a 24V output voltage can be used in a variety of applications such as power supplies, audio amplifiers, and control systems. Transformers are passive components that use electromagnetic induction to transfer electrical energy from one circuit to another. When selecting a transformer for a specific application, it is important to consider factors such as the input voltage, output voltage, maximum current, and frequency. In addition, the type of transformer (such as a step-up or step-down transformer) and the number of windings on the primary and secondary coils will affect the voltage and current output.

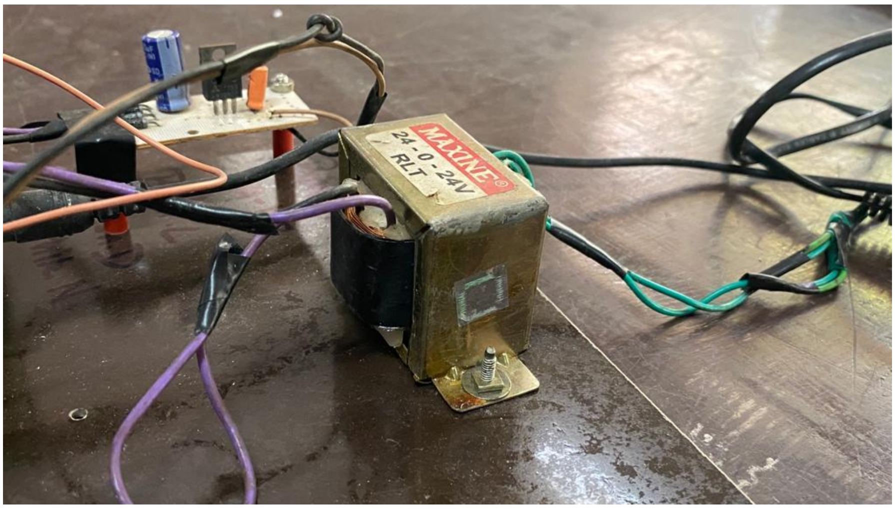

Fig 4.6 Transformer

4.8 PIC microcontroller

The PIC microcontroller PIC16f877a is one of the most renowned microcontrollers in the industry. This controller is very convenient to use, the coding or programming of this controller is also easier. One of the main advantages is that it can be write-erase as many times as possible because it uses FLASH memory technology. It has a total number of 40 pins and there are 33 pins for input and output. PIC16F877A is used in many PIC Microcontroller Projects. PIC16F877A also have many applications in digital electronics circuits. It is used in remote sensors, security and safety devices, home automation and in many industrial instruments. The figure 4.5 shows the top view of PIC16f877a microcontroller.

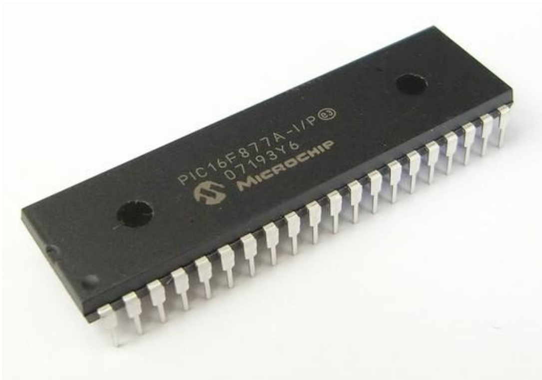

Fig. 4.7 PIC16f877a microcontroller

4.9 Pin configuration of PIC16f877a microcontroller

There are 40 pins of this microcontroller IC. It consists of two 8 bit and one 16bit timer. Capture and compare modules, serial ports, parallel ports and five input/output ports are also present in it. The pin configuration of PIC16f877a is shown in the figure 4.8

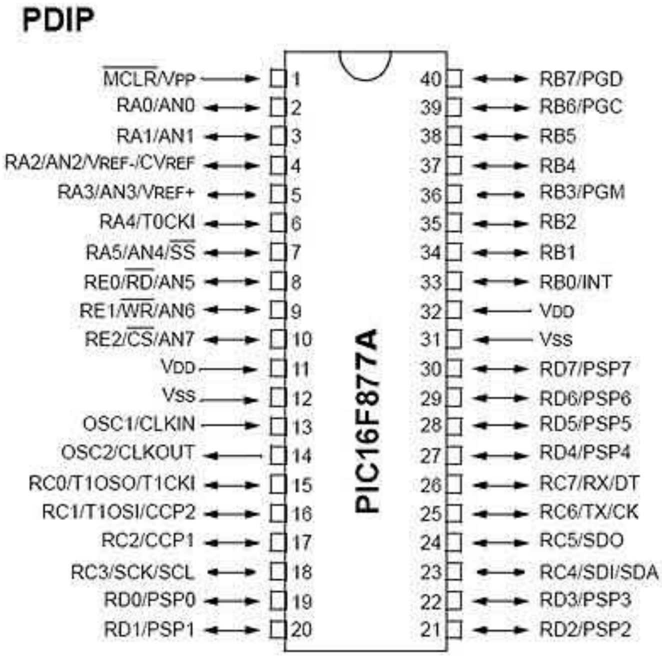

Fig. 4.8 Pin configuration of PIC16f877a microcontroller

4.10 BOOST CONVERTER CIRCUIT

A boost converter circuit is a type of DC-DC converter that is designed to increase the output voltage from a lower input voltage. It is a step-up converter that uses an inductor, a switching element (usually a MOSFET), a diode, a capacitor, and a load resistor to convert the input voltage to a higher voltage output. This circuit contains components of 2SK3878 MOSFET, IC 4427, 10A10 diode and connector pins. The hardware circuit of boost converter is shown in the figure 4.7.

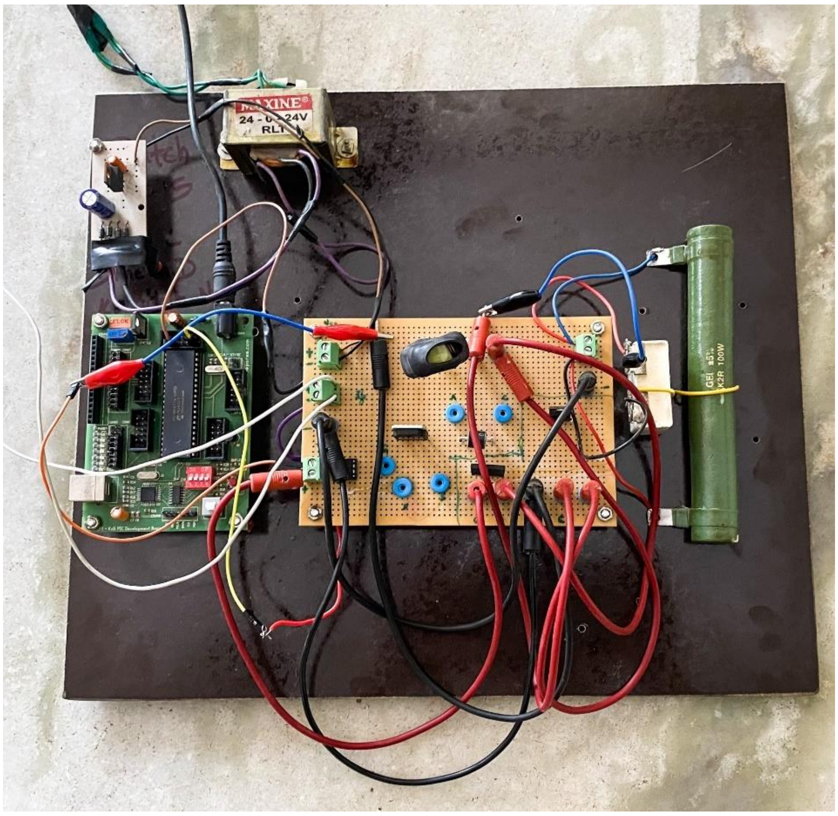

Fig 4.9 Hardware photograph of boost converter

4.11 HARDWARE RESULT

The results of the hardware implementation are viewed in the digital storage oscilloscope (DSO). A digital storage oscilloscope is which stores and analyses the signal digitally rather than using analog techniques. It is now the most common type of oscilloscope in use because of the advance trigger, storage and measurement features which it typically provides.

4.11.1 Input voltage waveform

Input voltage waveform of the boost converter is shown in the fig 4.8. It is observed from the digital storage oscilloscope (DSO), where the input voltage is equal to 12V at its steady state.

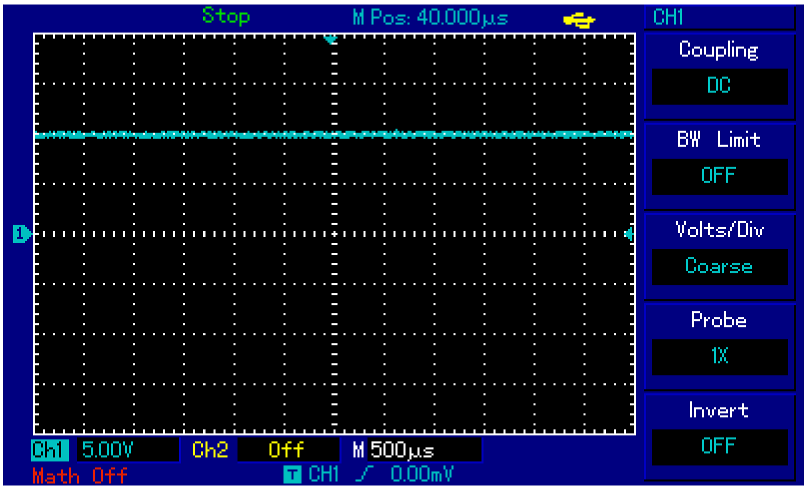

Fig. 4.10 Input voltage waveform of Boost Converter

4.11.2 Output voltage

The output voltage result of the Boost Converter is shown in the fig 4.9. It is measured in the Multimeter, where the output voltage is equal to 94.2V for input voltage of 12V at its steady state.

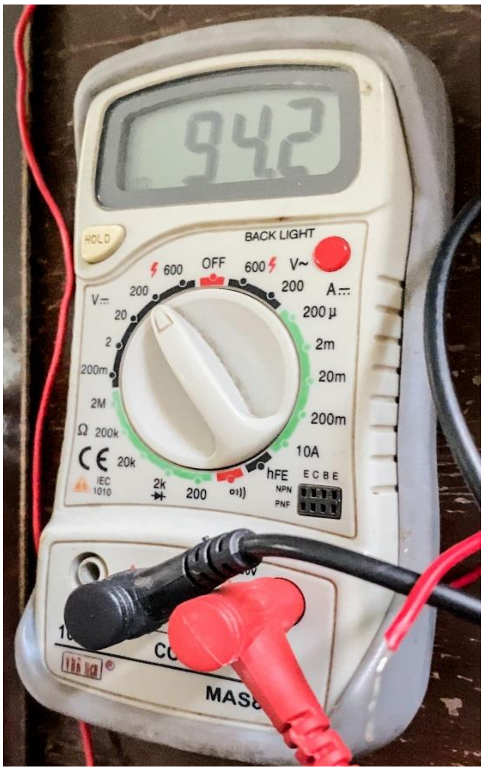

Fig. 4.11 Output voltage waveform of MDCP converter

4.11.3 Gate pulse waveforms

The gate pulse waveform to trigger the MOSFET in the boost converter is shown in the figure 4.10. It is observed from the waveform the switching frequency is equal to 100 KHz and the duty cycle is equal to 60 % .

Fig. 4.12 Gate pulse waveform of the Boost Converter

4.12 CONCLUSION

The hardware components for the proposed circuit of “Design and Analysis of Boost Converter using SiC MOSFET at High Duty Ratio” have been explained with their respective waveforms.

CHAPTER 5
CONCLUSION AND FUTURE SCOPE

5.1 CONCLUSION

The merit to be considered in the boost converter is that the output voltage is greater than the input voltage that's why we name that has 'boost'. Boost converter is used to boost up the voltage from lower level to higher level. In this project we have compared the efficiency of the Si and SiC MOSFET and analyzed its current and voltage respective to its input given. By using this boost converter topology is implemented. One of the advantages of the proposed converter is that since it is a voltage multiplier circuit and interleaved boost stage converter with high voltage gain, it has the flexible to be connected to independent sources while allowing power sharing. Hence the boost converter enhances output and reduces output stresses on switches and other losses which is clear for both simulation and theoretical results.

5.2 FUTURE SCOPE

- Opportunities abound for manufacturers of dc/dc converters. Both the module and on-board solutions providers are evolving to meet the needs of the system manufacturers that need multiple rails at low voltages.
- The converter companies continually push the limits with new packaging designs and increased levels of integration.
- Advanced materials, such as silicon-carbide (SiC) and gallium-nitride (GaN), are slowly becoming more cost effective in applications with high-temperature and high-power requirements (SiC) or high-performance information and communication technology (ICT) applications (GaN).

REFERENCES

[1] Muhammad H. Rashid, "Power Electronics, Circuits, Devices, and Applications", Third Edition, Pearson Education, Inc., 2004.

[2] Carl Nelson & Jim Williams, "Linear Technology, LT1070 Design Manual", 1986.

[3] Marty Brown, "Practical Switching Power Supply Design", New York: Academic Press, Inc., 1990.

[4] Irving M. Gottlieb, "Power Supplies, Switching Regulators, Inverters, & Converters", New York: McGraw-Hill, 1993.

[5] D. M. Mitchell, "DC-DC Switching Regulator Analysis", New York: McGraw-Hill, 1988.

[6] Anita Soni, "DC-DC Switching Boost Converter", ILLINOIS College of Engineering, 1999.

[7] G. Seguier, "Power Electronic Converters: DC-DC Conversion", New York, SpringerVerlag, Inc., 1993.

[8] Angaleaeshwari S (2021), IEEE Member, "Design and Execution of Quadratic Boost Converter in Renewable Energy Synergies", IEEE transactions on power electronics, Vol. 12, no. 9.

[9] K. I. Hwu, C. F. Chuang, and W. C. Tu, "High Voltage-Boosting Converters Based on Bootstrap Capacitors and Boost Inductors" IEEE Trans. On Industrial Elec., Vol., 60 No 6, June 2013.

[10] D. Nicolae, C. Richards, and J. van Rensburg. Boost converter with improved transfer ratio, in Proc. IEEE IPEC, 2010, pp. 76–81.

[11] Ned Mohan et.al. Power electronics. John Wiley and Sons, 1989.