APPENDIX 1

Design and Analysis of synchronous Buck Converter

PROJECT REPORT

By

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APPENDIX 2

BONAFIDE CERTIFICATE

This is to certify that this project report entitled “Design and Analysis of Synchronous Buck Converter” is submitted to Delhi Technological University, is a bonafide record of work done by “Pradyumn Tiwari, Yasharth Sharma and Himanshu” under my supervision.

Prof. Mini Srijeth

APPENDIX 3

Declaration by Author(s)

This is to declare that this report has been written by us. No part of the report is plagiarized from other sources. All information included from other sources have been duly acknowledged. We aver that if any part of the report is found to be plagiarized, we are shall take full responsibility for it.

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Introduction:

The synchronous buck converter, a linchpin in power electronics, orchestrates voltage regulation with meticulous precision, showcasing its prowess in efficiency and adaptability. Diverging from its non-synchronous counterpart, this converter integrates synchronous rectification, a technological leap that propels its performance to new heights.

At its essence, the synchronous buck converter employs a trio of components—inductors, capacitors, and switches—to elegantly step down voltage levels.

Its defining feature lies in the integration of actively controlled switches, typically MOSFETs, which supplant traditional diodes in the rectification process. This substitution yields a substantial reduction in power losses, culminating in a quantum leap in overall efficiency.

The virtues of the synchronous buck converter extend beyond mere efficiency gains. By curtailing both switching losses and diode conduction losses, it emerges as a stalwart solution for applications where energy conservation is paramount.

Its ability to operate at higher frequencies not only enables faster response times but also facilitates a more compact design, aligning seamlessly with the ongoing trend of miniaturization in electronic devices.

Yet, delving into the realm of synchronous buck converters demands a nuanced approach. Prudent component selection, strategic control strategies, and effective thermal management constitute the intricate dance required to unlock their full potential.

The delicate balance between efficiency and complexity underscores the artistry involved in the design of power electronics.

In an era where energy efficiency and compact design define technological progress, the synchronous buck converter stands as a technological marvel.

Its applications span a diverse spectrum, from powering portable electronics to enhancing the efficacy of renewable energy systems.

The continued evolution of the synchronous buck converter promises to redefine the landscape of power electronics, propelling innovation and efficiency to unprecedented levels.

Description of Components used:

For our project we have used the following components:

(a) Input supply voltage, Vin = 9V

Since, we’re designing our circuit in order to comply with the industry aspects, we’re taking input supply as 9V since, it is easily available as it is used in driving various industrial appliances.

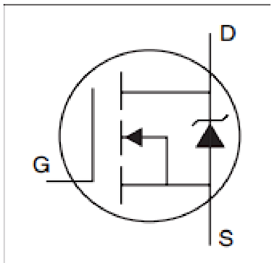
(b) Inductor, L=3mH

(c) Capacitor, C=100uF

(d) Resistor, R=10 ohm

(e) N-channel MOSFET

For our project we used IRF1407 N-channel MOSFET which is manufactured by International Rectifier, below is shown the internal structure of the IRF1407 N-channel MOSFET



The IRF1407 N-channel MOSFET is a common Power MOSFET used in Industrial Motor Drive applications. The MOSFET comes with various benefits over other N-channel MOSFETs available which includes:

(i) Advanced Process Technology

(ii) Ultra Low On-Resistance

(iii) Dynamic dv/dt Rating

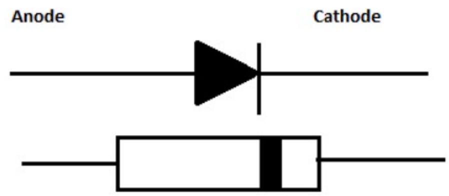
(iv) 175°C Operating Temperature

(v) Fast Switching

Ratings: Vds=75V, Rds(on)=6.7milli ohm

(f) PN junction diode

For our project we used 1N4148 PN junction diode which is a silicon based diode manufactured by OnSemi, the internal structure of the diode is shown below



The features of 1N4148 diode includes:

(i) Fast Switching Speed

(ii) General Purpose Rectification

(iii) Silicon Epitaxial Planar Construction

(g) PWM input to drive N-channel MOSFET (5V input pulse, Rise time=1ns, Fall time=1ns, Time period=100us, Duty cycle=40% for driving high side switch and 60% for driving low side switch in case of Synchronous Buck Converter)

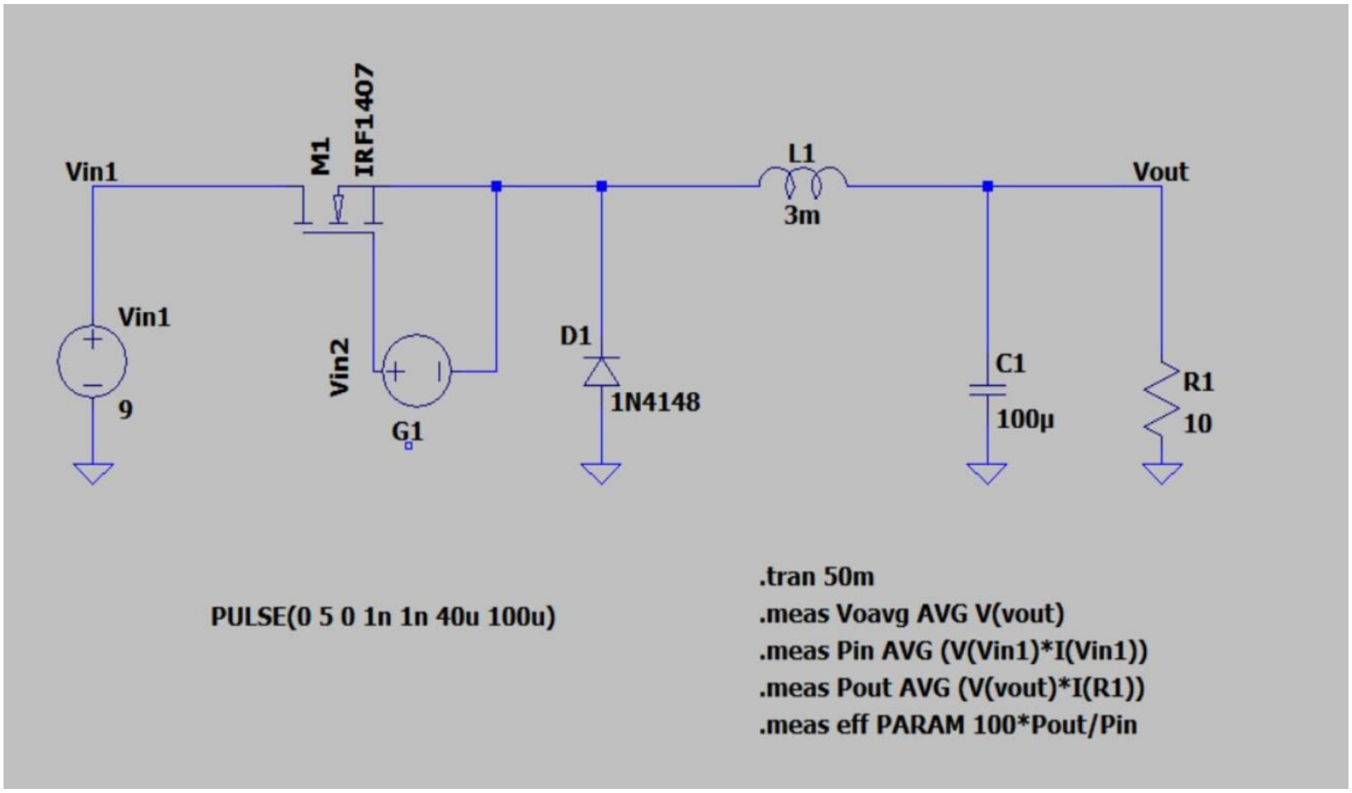
Simulation of Buck Converter:

Embarking on the simulation and analysis of a Buck Converter using LTspice has been an enlightening journey into the intricacies of power electronics. The focal point of this exploration was the meticulous examination of operational parameters, particularly the duty cycle of MOSFETs, to unravel the efficiency dynamics of the converter.

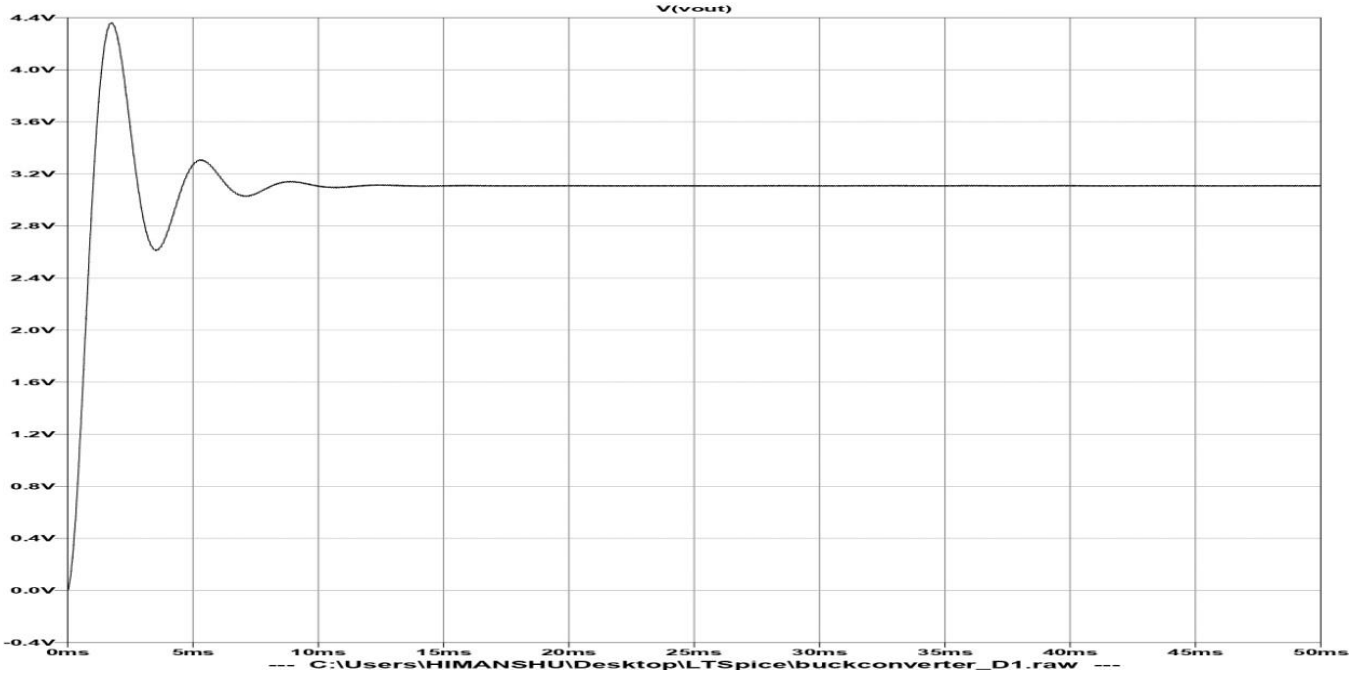
Our simulation yielded a noteworthy efficiency of 84%, offering a valuable snapshot of the converter's performance under specific conditions. The chosen duty cycle of 40% played a pivotal role in shaping this efficiency, laying the groundwork for future optimizations. It's clear that further refinement, achieved through adjustments in duty cycle, component values, and switching frequency, could unlock higher efficiency levels.

As we conclude this phase of the project, the insights gained pave the way for future explorations into the world of Buck Converters. The recommendations for duty cycle optimization, sensitivity analysis of component values, and the potential implementation of feedback control mechanisms set the stage for continued refinement and innovation in the quest for more efficient power conversion systems.

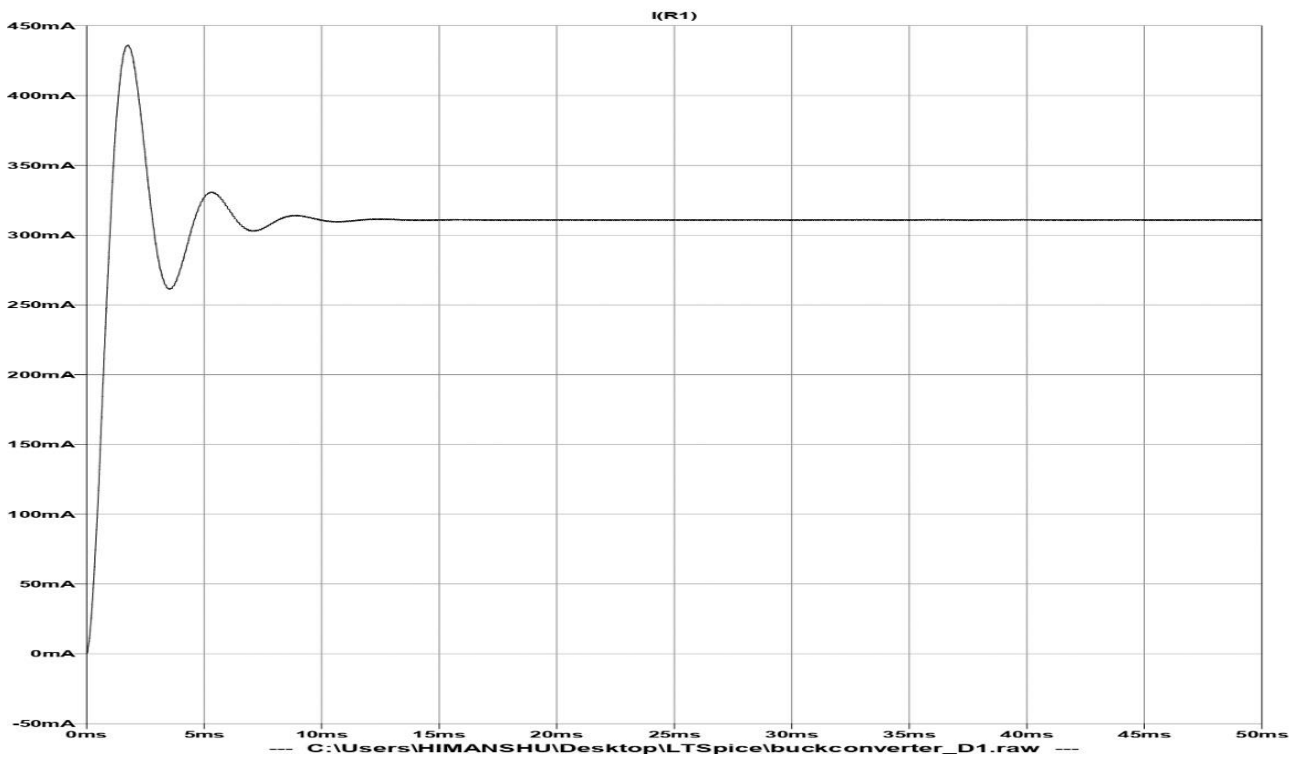
This note encapsulates the current chapter of our journey—a chapter that opens the door to further inquiry, experimentation, and the pursuit of excellence in power electronics.



Simulation Result of Buck Converter



Output Voltage Vout w.r.t. time



Output Current Iout w.r.t. time

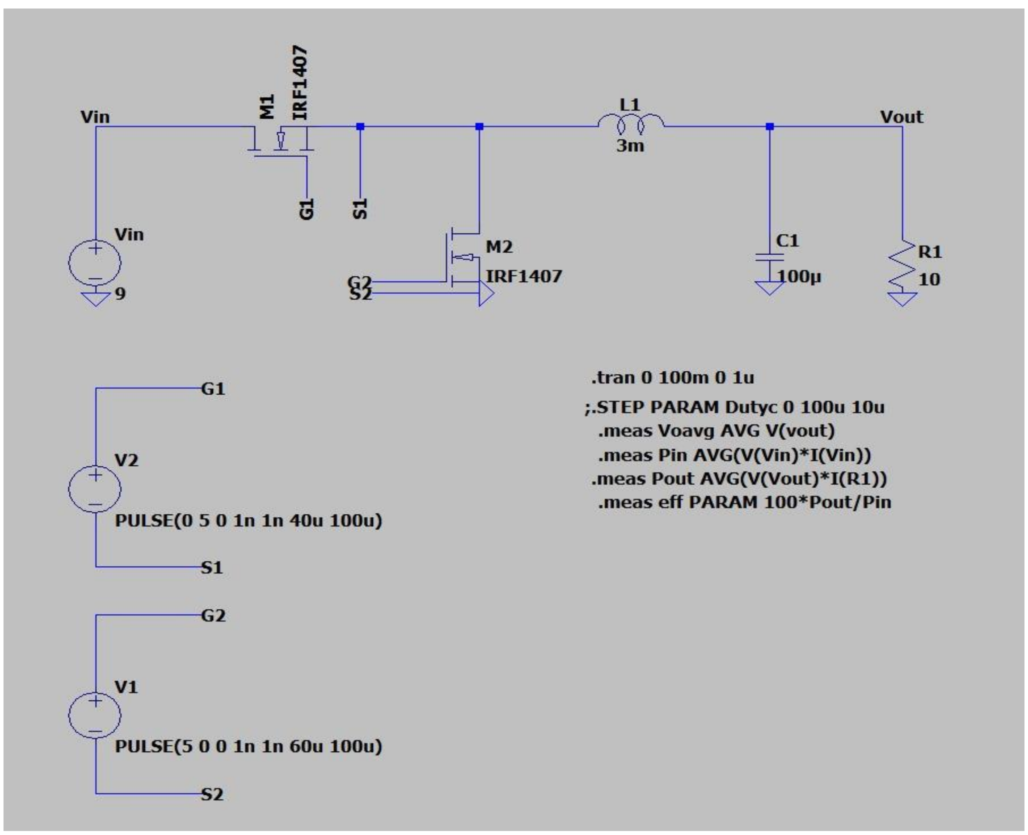
Simulation Of Synchronous Buck Converter:

Embarking on the design and simulation of a Synchronous Buck Converter has been an exhilarating journey into the realm of power electronics. The circuit, meticulously crafted with MOSFETs, inductors, capacitors, resistors, and a voltage source, aimed to exemplify efficiency in power conversion.

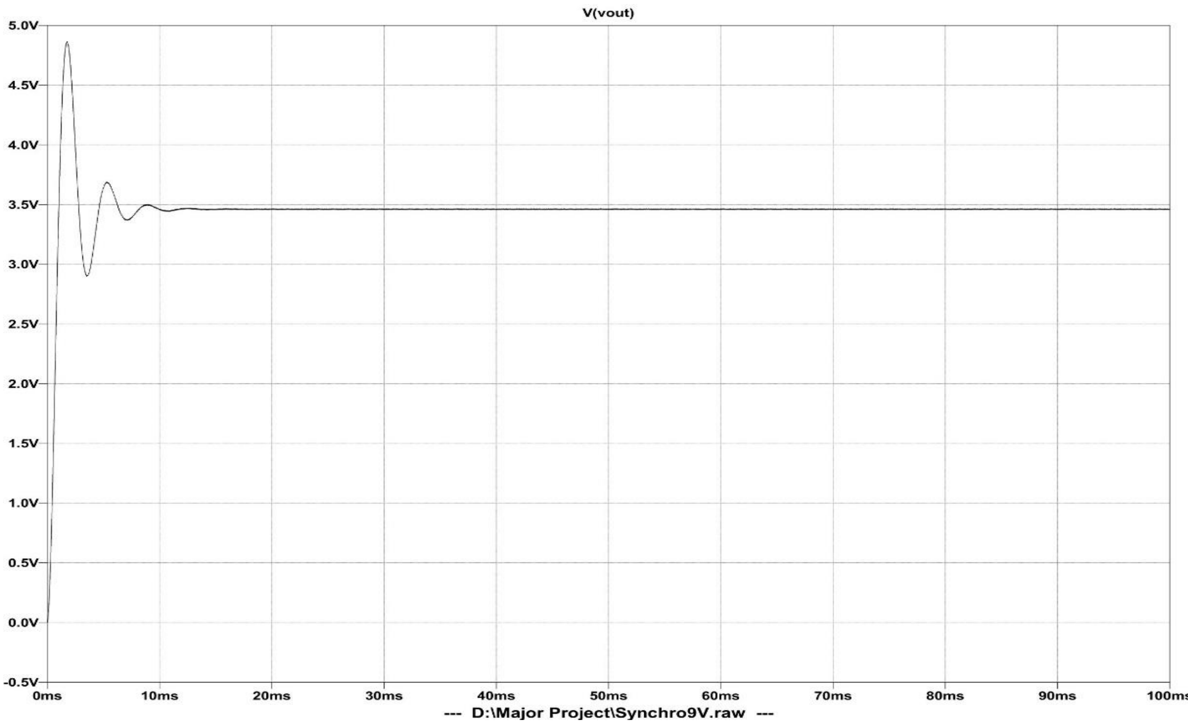
Key design parameters were meticulously chosen: a 40% duty cycle for the MOSFETs, a 3mH inductor, a 100 microfarad capacitor, and a 10-ohm resistor. The simulation unfolded with promising results, showcasing an impressive efficiency of 94.8281%. This high efficiency is a testament to the adept selection and integration of components within the circuit.

In the realm of waveforms, our observation encompassed the current waveform, voltage waveform, current ripple, and voltage ripple. These visualizations provide a nuanced understanding of the converter's dynamic behavior, offering valuable insights into its stability and overall performance.

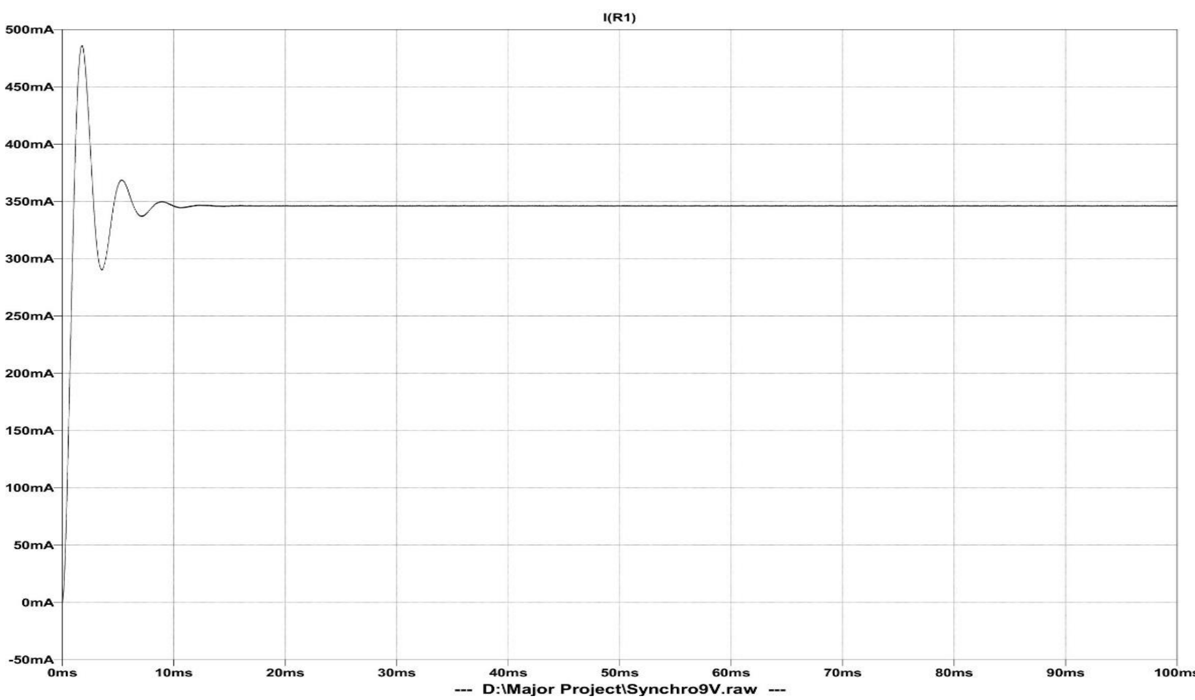
As we conclude this simulation, the achieved efficiency underscores the success of our design choices. The meticulous examination of waveforms enhances our understanding of the converter's transient and steady-state characteristics. This accomplishment lays the foundation for further exploration, encouraging iterative refinement, and the pursuit of even greater efficiency in future power electronics projects.



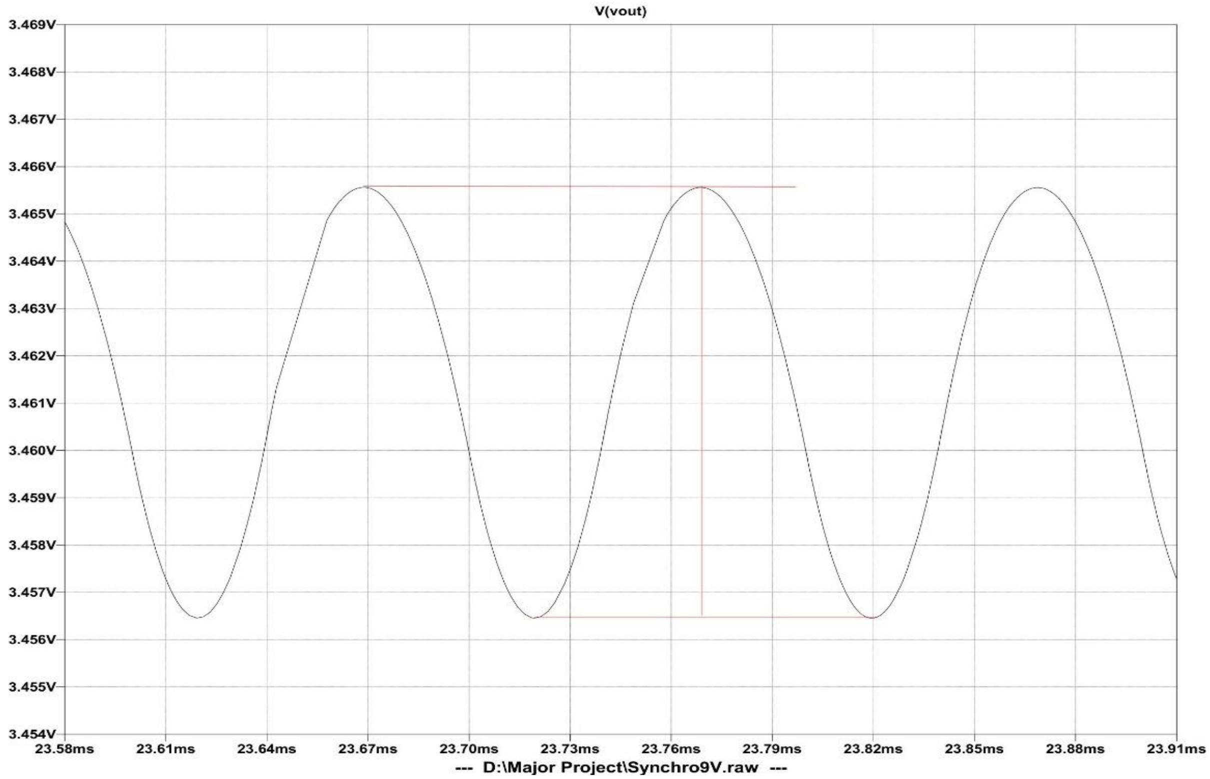
Simulation Result of Synchronous Buck Converter



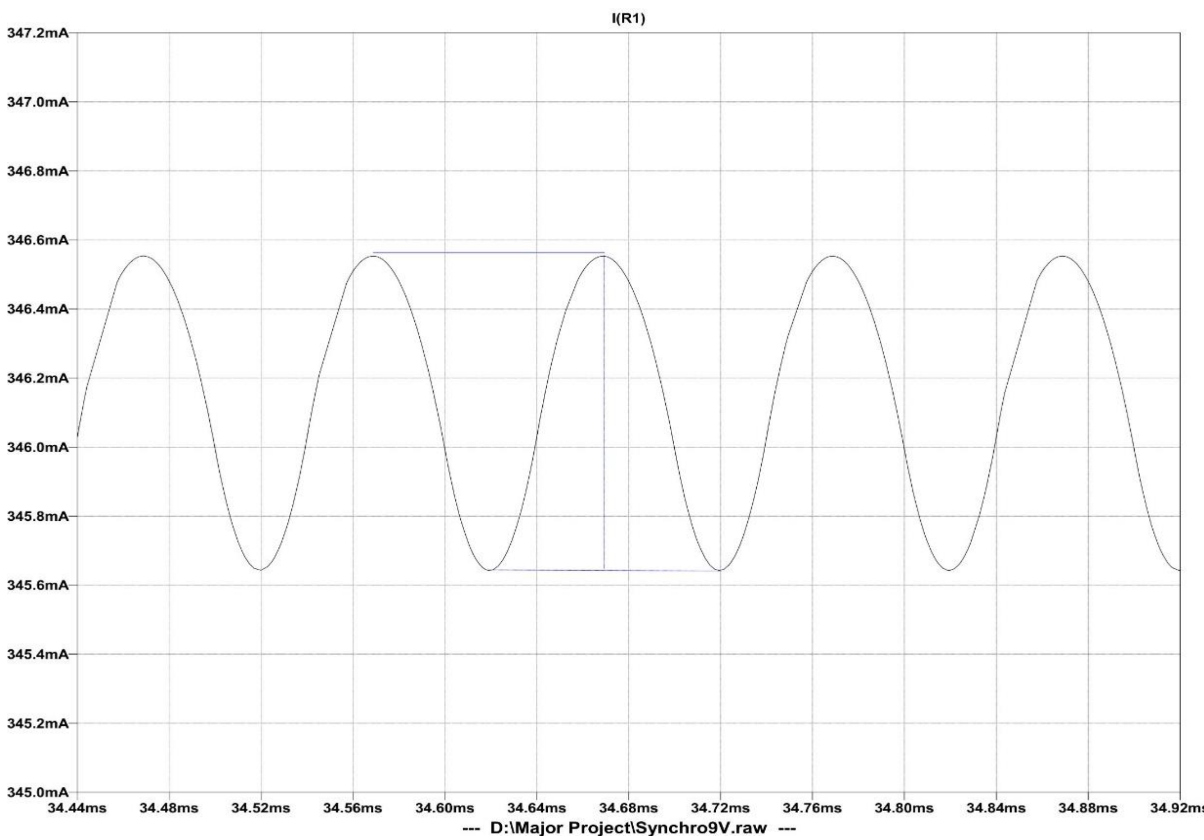
Output Voltage Vout w.r.t. time



Output Current Iout w.r.t. time



Output Voltage Ripple



Output Current Ripple

Calculation of parameters:

The parameters used in the circuit namely Inductance, Resistance and Capacitance, we verified the parameter values by hand calculations. The formulae and calculations are shown below:

- Maximum Duty Cycle (D) = Vout/(Vin*Effciency) (ideally, assuming efficiency to be 100%)
- Inductor Ripple Current ΔIL = (Vin-Vout)*D / fs*L
- Inductance (L) = Vout*(Vin-Vout) / (ΔIL*fs*Vin)
- Resistance (R) = Vout / IL (ideally, assuming there is no current drawn by capacitor)
- Capacitance (C) = ΔIL / (8*fs* ΔVout)

For our project we took fs (switching frequency) = 10KHz

Desired output voltage (Vout) = 3.6V (we're aiming to implement a buck converter which efficiently Steps down the DC input 9V to 3.6V)

Desired output voltage ripple (ΔVout) < 1% (we're taking 0.009V for our project)

Desired current ripple (ΔIL) ~ 20%

We've obtained the following values after calculation:

Inductance (L)=3mH

Capacitance (C) = 100.8uF

Resistance (R) = 10.415 ohm

Inductor Ripple Current (ΔIL) = 73.3831 mA (21.2089%)

Output Ripple Voltage (ΔVout) = 9.0mV

Output Voltage (Vout) = 3.4599V

Inductor Current (IL) = 346.3768mA

Output Current (Iout) = 345.643mA

Calculated Efficiency = 96.10%

Observed Efficiency = 94.8281%

Comparison:

Buck Converter	Synchronous Buck Converter
Output Voltage (Vout) = 3.1109V	Output Voltage (Vout) = 3.4599V
Efficiency = 84.6729% (observed) = 86.4141% (calculated)	Efficiency = 94.8281% (observed) = 96.10% (calculated)
Inductor Ripple Current (ΔIL) = 78.18mA	Inductor Ripple Current (ΔIL) = 73.3831mA
Output Ripple Voltage (ΔVout) = 9.56mV	Output Ripple Voltage (ΔVout) = 9.1mV
Inductor Current (IL) = 310mA	Inductor Current (IL) = 346.3768mA
Output Current (Iout) = 311.59mA	Output Current (Iout) = 345.643mA

From the above simulation results and observed values we can conclude the following differences between Traditional Buck Converter and Synchronous Buck Converter.

Features	Buck Converter	Synchronous Converter
Circuit	Single MOSFET + Diode	Two MOSFETs
Operation	Diode rectifies current	Bi-directional current flow
Losses	Higher conduction losses due to diode	Lower conduction losses due to MOSFETs
Efficiency	Lower, typically 80-90%	Higher, typically 90-95%
Cost	Lower	Higher
Complexity	Simpler circuit	More complex circuit
Applications	Low-efficiency applications	High-efficiency applications, low output voltages, high duty cycles

Future Prospects:

- Integration of Voltage Drivers For further Optimization in efficiency and reduction in losses.
- Smart Buck Converter using closed loop control.
- Implementation Of Hardware model.

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