DESIGN OF NON-ISOLATING BOOST CONVERTER

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Abstract: *In some remote regions, the supply of electricity is not constant. And they heavily rely on the electricity they get from solar panels which do not produce a very large amount of power. Herewith the help of a Boost Converter we can amplify the output we get from the solar panels, which can give us more supply. A Boost Converter is a DC-DC converter which amplifies the input voltage. With some modifications, it can be used in everyday households too. This can greatly reduce the power consumption which we are supplied with by the government. Proteus design suite was used to observe the functioning and the output of the boost converter. The program was written in Keil µvision. The main aim was to observe the working of the boost converter and to observe the change in output with change in the duty ratio. The simulation results in form of tables and the plots were presented. The result of this was that we can observe that there is a clear range in which we can get maximum output from the converter.*

Index Terms: Solar panels, Boost converter, amplify, DC-DC converter, simulation, duty ratio.

I. Introduction

A boost converter (step-up converter) is a DC-to-DC power converter that steps up (while stepping down current) from its input (supply) to its output (load). Power for the boost converter can come from any suitable DC source, such as batteries, solar panels, rectifiers, and DC generators. A process that changes one DC voltage to a different DC voltage is called DC to DC conversion. A boost converter is a DC to DC converter with an output voltage greater than the source voltage. A boost converter is sometimes called a step-up converter since it "steps up" the source voltage. Since power (P=VI) must be conserved, the output current is lower than the source current. The solar panel acts a DC source for the boost converter. The C program is loaded on the microcontroller. It will control the MOSFET which will control the switching action and duty cycle of the microcontroller. The frequency is also given to the circuit through the microcontroller. As per the DC voltage input and the program the boost converter amplifies the voltage which is then converter into AC voltage through the inverter and then it is connected to the grid of use.

II. Boost Converter

Figure 1 depicts the equivalent circuit of Boost Converter. With reference to Figure 1, the components used in a Boost Converter are:

V_{in}: Supply DC Voltage

I_{in}: Supply DC Current

Inductor

MOSFET IRF540N

Diode 6TQ045

Capacitor

Resistive Load

I_{out}: Output DC Current

V_{out}: Output DC Voltage

i: Inductor Current

Ground

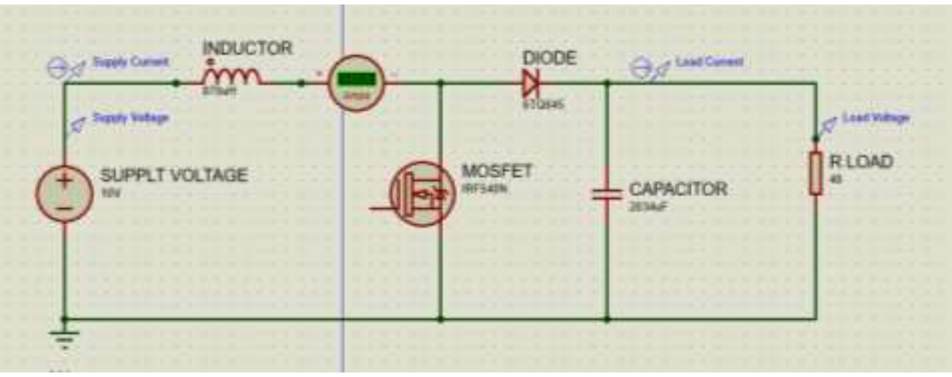


Figure 1 Equivalent Circuit of Boost Converter

T_{on}: Switch on time
T_{off} : Switch off time
α: Duty Ratio

$$T = T_{on} + T_{off} \tag{1}$$

$$\alpha = \frac{T_{on}}{T} \tag{2}$$

At T_{on},

$$V_{in} = L\,\frac{di}{dt} \tag{3}$$

$$V_{in} = \frac{L\,.\,di}{T_{on}} \tag{4}$$

$$T_{on} = \alpha.T \tag{5}$$

$$di = \frac{V_{in}\,.\,\alpha\,.\,T}{L} \tag{6}$$

At T_{off} ,

$$V_{out} = L\,\frac{di}{dt} + V_{in} \tag{7}$$

$$V_{out} = \frac{L\,.\,di}{T_{off}} + V_{in} \tag{8}$$

$$T_{off} = (1 - \alpha).T \tag{9}$$

$$di = \frac{(V_{out} - V_{in})\,.\,(1\text{-}\alpha)\,.\,T}{L} \tag{10}$$

When,

$$di\,(T_{on}) = di\,(T_{off}) \tag{11}$$

$$V_{out} = \frac{V_{in}}{1\text{-}\alpha} \tag{12}$$

Equation 11 shows that the change in current is equal when the switch is on and when the switch is off.
Equation 12 shows the output voltage of the Boost Converter.
Figure 2 shows the block diagram of the Boost Converter

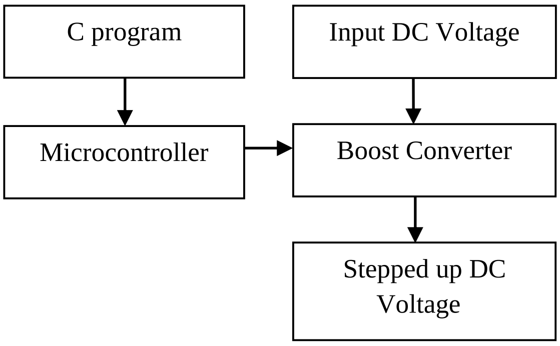


Figure 2 Block diagram of a Boost Converter

III. Elements of Boost Converter

3.1 Microcontroller AT89C51

The AT89C51 is a low-power, high-performance CMOS 8-bit microcomputer with 4K bytes of Flash programmable and erasable read only memory (PEROM). The device is manufactured using Atmel's high-density non-volatile memory technology and is compatible with the industry-standard MCS-51 instruction set and pin-out. The on-chip Flash allows the program memory to be reprogrammed in-system or by a conventional non-volatile memory programmer. By combining a versatile 8-bit CPU with Flash on a monolithic chip, the Atmel AT89C51 is a powerful microcomputer which provides a highly-flexible and cost-effective solution to many embedded control applications.

Figure.3 shows the pin diagram of AT89C51

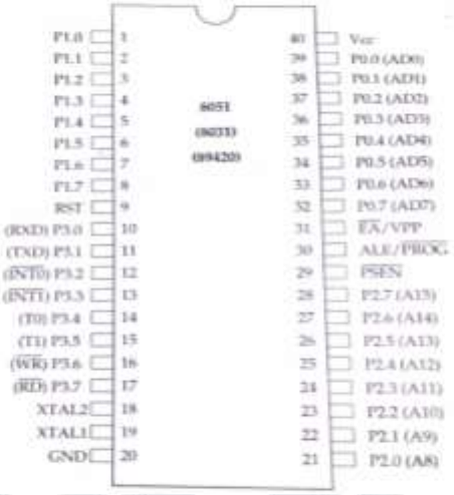


Figure 3 Pin diagram of AT89C51 [4]

3.2 MOSFET IRF540N

A semi-conductor switch was needed for connecting and disconnecting the load to the supply, here a Metal Oxide Semiconductor Field Effect Transistor is used. [11]

Drain to Source Voltage: 100V

Drain to Gate Voltage (RGS = 20kΩ): 100V

Gate to Source Voltage: ±20V

Drain current (TC= 25°C, VGS = 10V): 33A

Power Dissipation: 120W

Operating and Storage Temperature: -55°C to 175°C

Figure 4 shows a diagram of a MOSFET

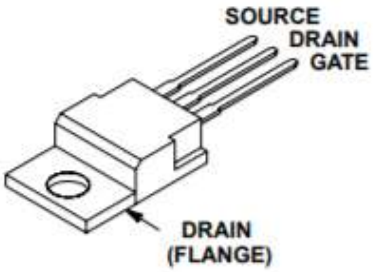


Figure 4 MOSFET IRF540N

3.3 Inductor

An inductor, also called a coil, chokes, or reactor, is a passive two-terminal electrical component that stores energy in a magnetic field when electric current flows through it. An inductor typically consists of an insulated wire wound into a coil around a core. When the current flowing through an inductor changes, the time-varying magnetic field induces an electromotive force (e.m.f.) (voltage) in the conductor, described by Faraday's law of electromagnetic induction. According to Lenz's law, the induced voltage has a polarity (direction) which opposes the change in current that created it. As a result, inductors oppose any changes in current through them. An inductor is characterized by its inductance, which is the ratio of the voltage to the rate of change of current. In the International System of Units (SI), the unit of inductance is the henry (H) named for 19th century American scientist Joseph Henry. In the measurement of magnetic circuits, it is equivalent to weber/ampere. Inductors have values that typically range from 1 µH (10^{-6} H) to 20 H. Many inductors have a magnetic core made of iron or ferrite inside the coil, which serves to increase the magnetic field and thus the inductance. [12]

V_{in}: Supply Voltage
V_{out}: Output Voltage
V_d: Forward voltage drop of MOSFET
f: Frequency of operation
Δi: Ripple Current

$$L = \frac{V_{in} \cdot (V_{out} + V_d - V_{in})}{\Delta i \cdot f \cdot V_{out} \cdot V_d} \text{ [9]} \tag{13}$$

Equation 13 shows how to calculate the value of inductor

3.4 Capacitor

A capacitor is a device that stores electrical energy in an electric field. It is a passive electronic component with two terminals. The effect of a capacitor is known as capacitance. While some capacitance exists between any two electrical conductors in proximity in a circuit, a capacitor is a component designed to add capacitance to a circuit. The capacitor was originally known as a condenser. This name and its cognates are still widely used in many languages, but rarely in English, one notable exception being condenser microphones, also called capacitor microphones. The physical form and construction of practical capacitors vary widely and many types of capacitor are in common use. Most capacitors contain at least two electrical conductors often in the form of metallic plates or surfaces separated by a dielectric medium. A conductor may be a foil, thin film, sintered bead of metal, or an electrolyte. The non-conducting dielectric acts to increase the capacitor's charge capacity. Materials commonly used as dielectrics include glass, ceramic, plastic film, paper, mica, air, and oxide layers. Capacitors are widely used as parts of electrical circuits in many common electrical devices. Unlike a resistor, an ideal capacitor does not dissipate energy, although real-life capacitors do dissipate a small amount. [13]

I_{in}: Input Current
α: Duty ratio
f: Frequency of operation
Δv: ripple voltage

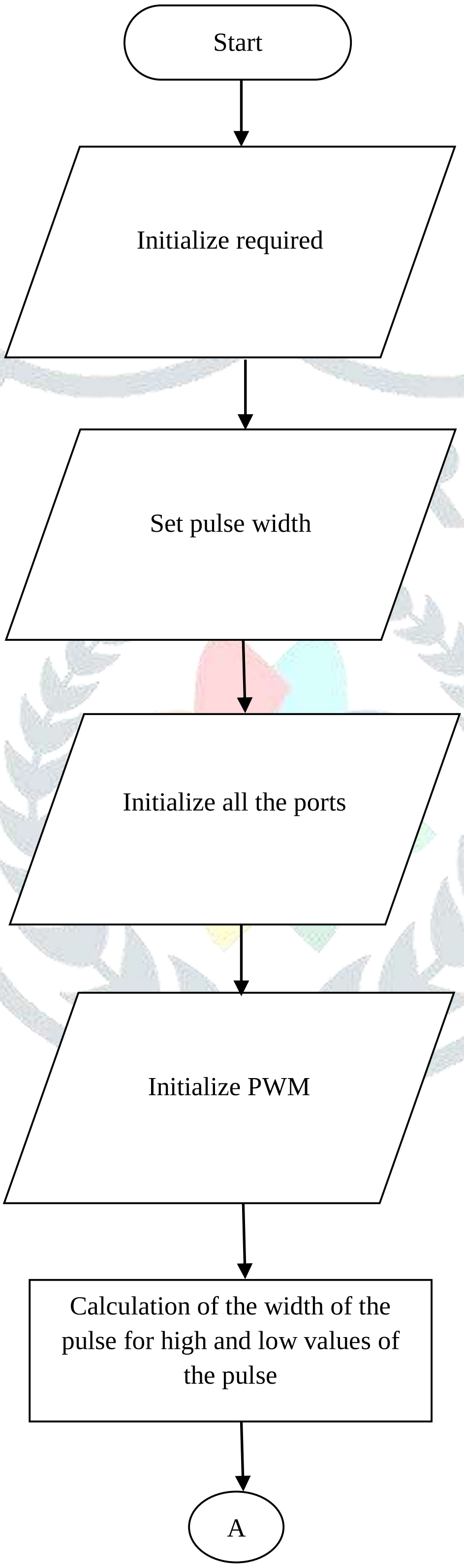
$$C = \frac{I_{in} \cdot \alpha}{f \cdot \Delta V} \text{ [10]} \tag{14}$$

Equation 14 shows how to calculate the value of capacitor

IV. TRIGGERING MOSFET

MOSFET needs to be trigger on the desired frequency using a C Program which needs to be compiled in a C compiler. Here we are using Keil to compile and to create a Hex file. Then we are using this Keil file to trigger MOSFET using microcontroller AT89C51.

Figure 5 shows the block diagram of the C program



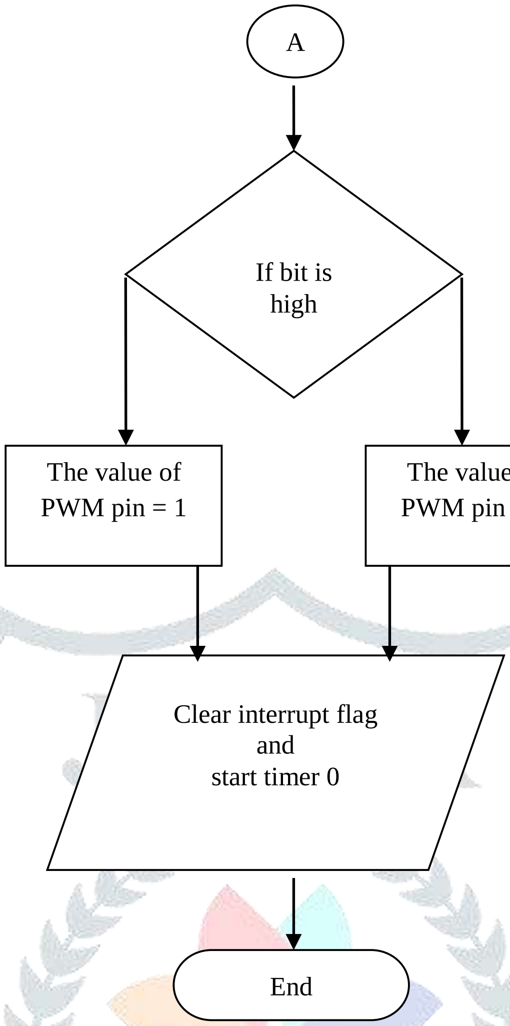


Figure 5 Block diagram of C program

V. RESULTS

V_{in}: 10V
L: 870μH
MOSFET IRF540N
Diode 6TQ045
C: 2034μH
R: 40Ω
α: 50%, 75%
f: 2.8kHz

5.1 Proteus Simulation Circuit

Figure 6 shows the connection of microcontroller AT89C51 with the MOSFET and its connection with the Boost Converter. The output at pin P2.0 is given to the input of the MOSFET.

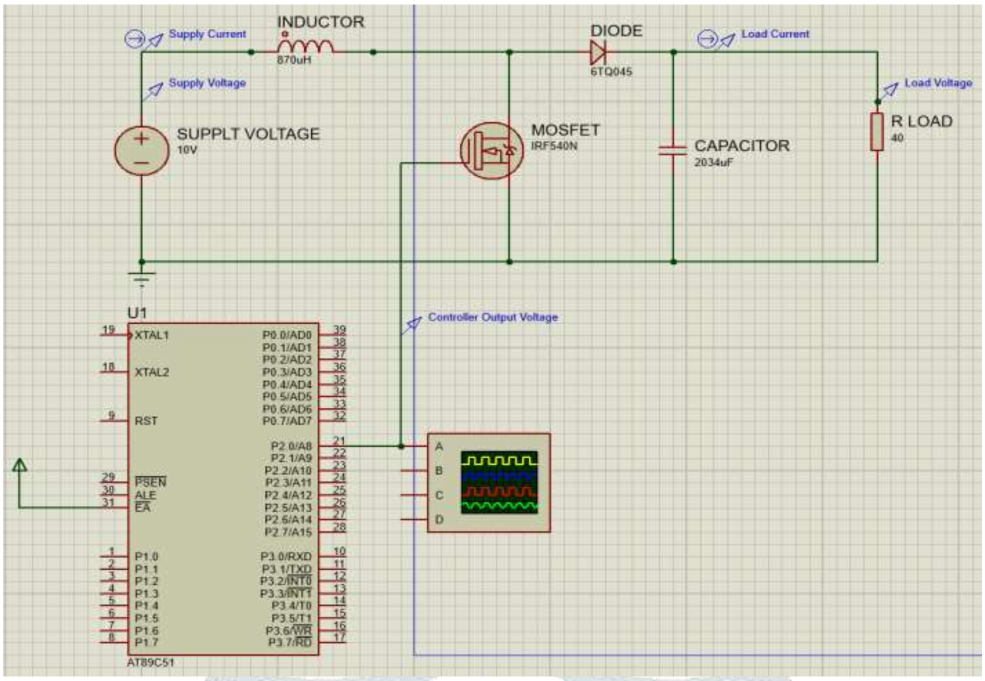


Figure 6 Design of Non-Isolated Boost Converter

5.2 Output of Oscilloscope at α =75%

Figure 7 shows the gate pulses.
f =2.8 kHz
T (Seconds) = 0.357 m
T_{in} (Seconds) = 0.268 m
T_{off} (Seconds) = 0.089 m
X-axis (Seconds) = 195m-200m
Y-axis (Voltage) = 0-6

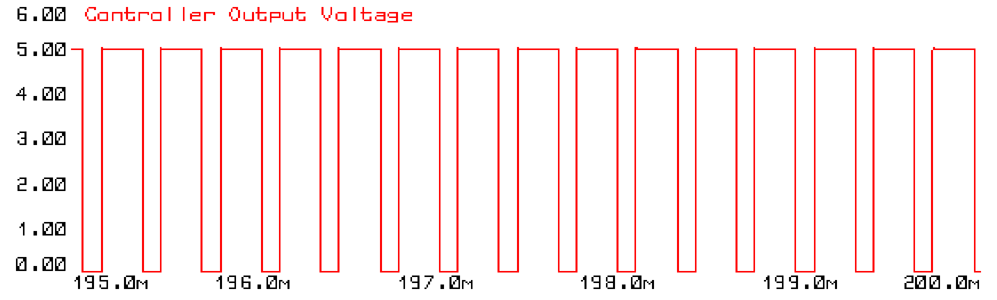


Figure 7 Gate Pulses

Figure 8 shows the input DC Voltage.
V_{in} = 10V.
X-axis (Seconds) = 0m-200m
Y-axis (Voltage) = 0-20

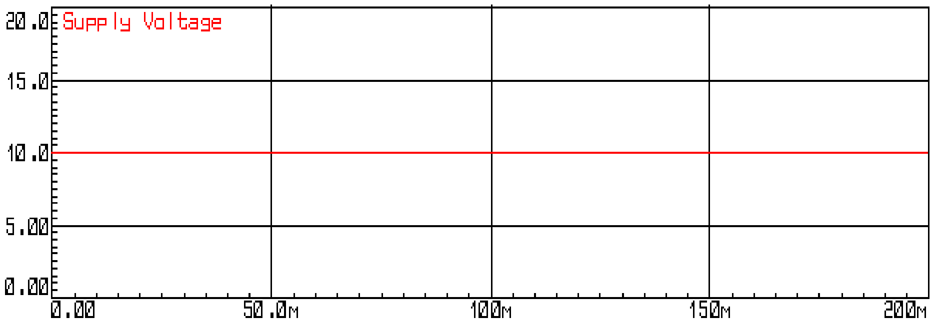


Figure 8 Supply DC Voltage

Figure 9 shows the transient and steady state value of input DC Current.
I_{in} = 2.55A
X-axis (Seconds) = 0m-200m
Y-axis (Ampere) = 0-30

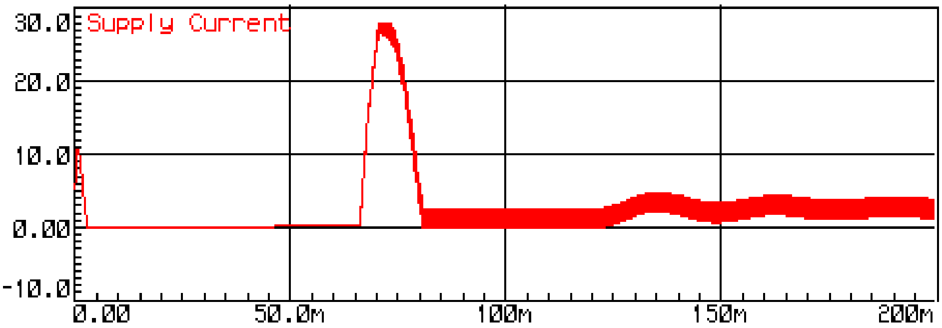


Figure 9 Supply DC Current

Figure 10 shows the transient and steady state value of output DC Voltage across R load.

V_{out} = 31.8V

X-axis (Seconds) = 0m-200m

Y-axis (Voltage) = 0-50

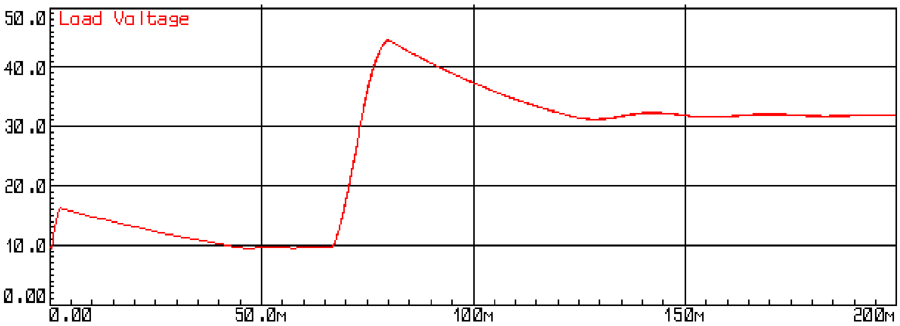


Figure 10 Output DC Voltage

Figure 11 shows the transient and steady state value of output DC Current.

I_{out} = 0.79A

X-axis (Seconds) = 0m-200m

Y-axis (Ampere) = 0-1.5

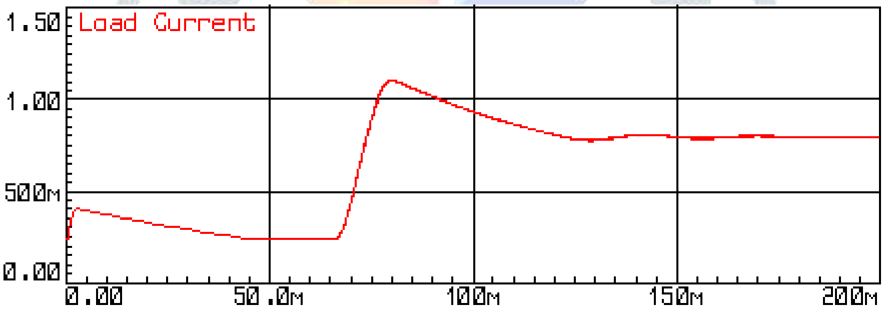


Figure 11 Output DC Current

5.3 Output of Oscilloscope at α =50%

Figure 12 shows the gate pulses.

f = 2.8 kHz

T (Seconds) = 0.357 m

T_{in}(Seconds) = 0.179 m

T_{off}(Seconds) = 0.179 m

X-axis (Seconds) = 195m-200m

Y-axis (Voltage) = 0-6

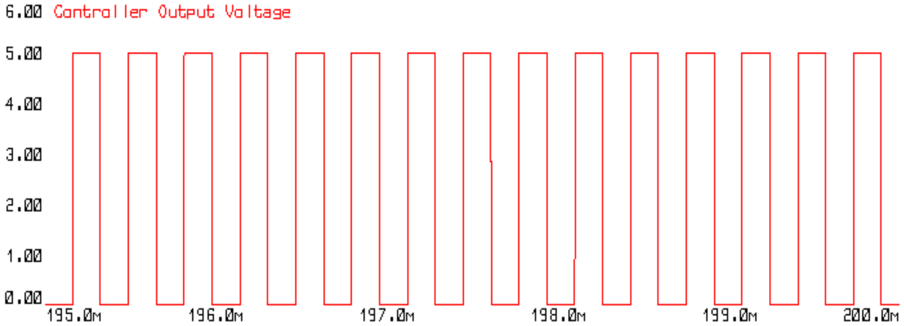


Figure 12 Gate Pulses

Figure 13 shows the input DC Voltage.

V_{in}= 10V.
X-axis (Seconds) = 0m-200m
Y-axis (Voltage) = 0-20

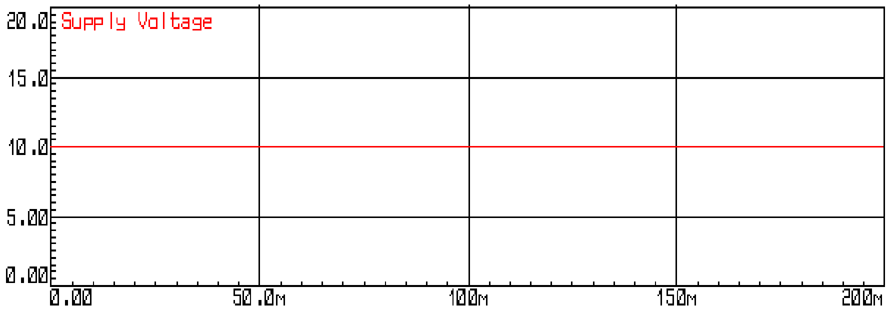


Figure 13 Supply DC Voltage

Figure 14 shows the transient and steady state value of input DC Current.
I_{in} = 0.77A
X-axis (Seconds) = 0m-140m
Y-axis (Ampere) = 0-20

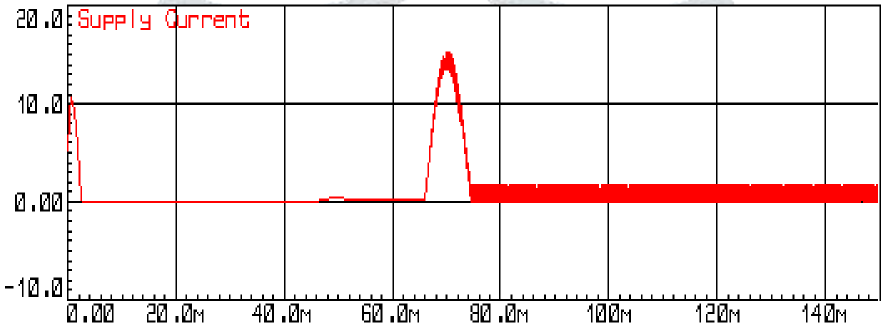


Figure 14 Supply DC Current

Figure 15 shows the transient and steady state value of output DC Voltage across R load.
V_{out}= 19.14V
X-axis (Seconds) = 0m-140m
Y-axis (Voltage) = 0-30

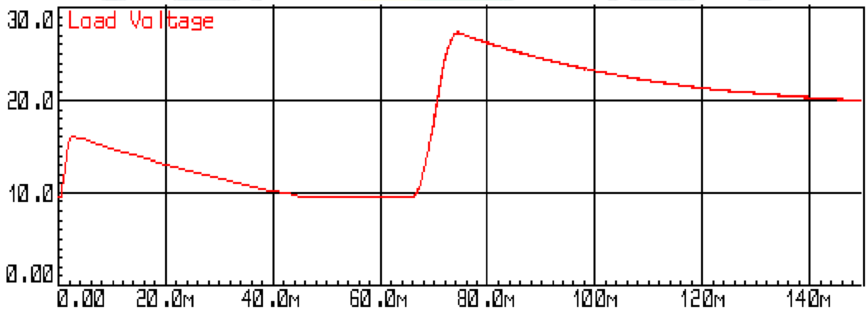


Figure 15 Output DC Voltage

Figure 16 shows the transient and steady state value of output DC Current.
I_{out} = 0.42A
X-axis (Seconds) = 0m-200m
Y-axis (Ampere) = 0-0.8

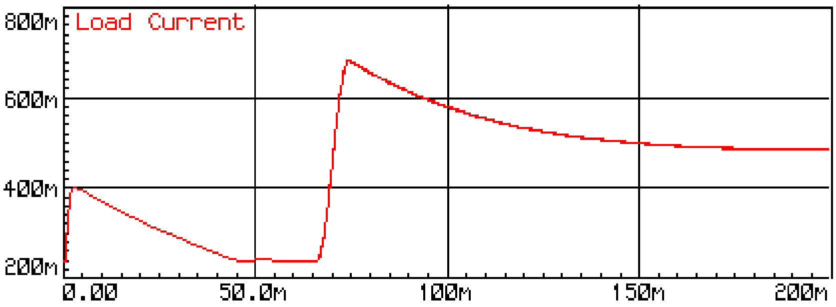


Figure 16 Output DC Current

5.4 Output at different values of α

Till α=95%, the value of V_{out} will increase, then the value of V_{out}will decrease. This is because due to the increased Ton time period, inductor will get fully charged and when fully charged the inductor will behave as a short circuit so the voltage across load will be only V_{in}.

Table 1 shows different values of V_{out} at different α

Table 1 V_{out} vs α

Duty Ratio in %	V_{out} in Volts
10	8.32
20	10.37
30	12.62
40	15.07
50	19.14
60	21.31
70	26.13
80	34.74
90	56
95	55.42
99	15.45

Figure 17 shows the graph of V_{out} vs α

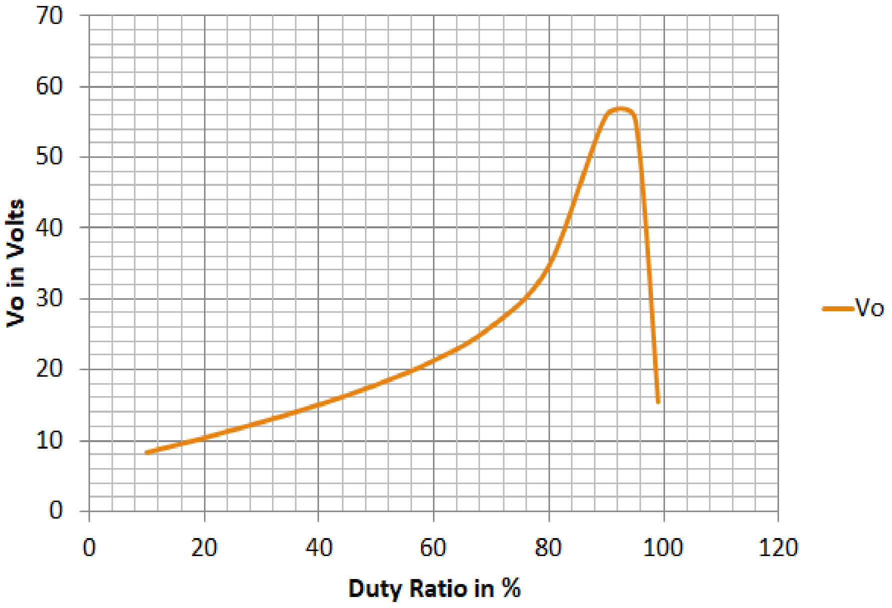


Figure 17 V_{out} vs α

VI. CONCLUSION

We designed a Boost Converter, wrote a C Program and observed the output in PSIM, Proteus and Keil µVision 5. We observed the difference between theoretical and simulated values of the Boost converter which will help us in the making of a functional boost converter. The boost converter designed by us is a Non-isolated boost converter.

VII. FUTURE SCOPE

In future, ultra high frequency switches will be there to control the on and off time of the circuit. This helps in better efficiency of the converter. These converters can be connected to Solar Panels for high output and then connect to an inverter to convert it to Alternating Voltage.

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