Design and Analysis of DC-DC Boost Converter

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Abstract

This paper demonstrates the design of a working prototype of 5-12V DC-DC Boost Converter. The boost converter circuit is designed using MOSFET, Resistor, Capacitor, Inductor and Diode. The key principle that drives the boost converter is the tendency of an inductor to resist changes in current. Inductor is designed using ferrite pot core and windings. This paper briefly reviews the technology used in switched mode power supplies for DC to DC conversion for transferring energy from input to output. Simulation studies are performed using MATLAB tool to validate the proposed scheme as well as hardware practical results.

1. Introduction

The widespread use of battery operated portable devices such as cell phones and laptops has created the need for DC to DC conversion power supplies such as switched mode power supplies. The prominence of distributed energy sources such as solar photovoltaic systems, which produce DC power has created a demand for DC to DC converters. DC converters are widely used for traction motor control in electric automobiles, trolley cars, marine hoists, forklifts trucks, and mine haulers. They provide high efficiency, good acceleration control and fast dynamic response. They can be used in regenerative braking of DC motors to return energy back into the supply. This attribute results in energy savings for transportation systems with frequent steps. DC converters are used in DC voltage regulators; and also are used, with an inductor in conjunction, to generate a DC current source, specifically for the current source inverter.[1] In this paper, some mathematical derivations are given first, and second, simulated and experimental results are provided to verify the effectiveness of the proposed voltage-boosting converter topology.

2. Mathematical Model

The mathematical model for boost converter performance formulae described by as follows:

Calculation

Basic formula

$$(V_o)/V_i = 1/(1-D) \tag{1}$$

Where V_o = Output voltage

V_i = Input voltage

D = Duty cycle

Solving for V_o = 12V and V_i=5 V

We get D=59 %

Also the Ripple Current comes to be:

$$\text{Ripple Current} = V_i(V_o-V_i)/fLV_o \tag{2}$$

And the Ripple Voltage is:

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$$\text{Ripple Voltage} = (I_o*D)/F_c \tag{3}$$

3. Test Setup

The boost converter was built on a standard breadboard. The 5V DC input voltage was supplied by a DC source. All DC measurements were taken using multimeter and all waveforms were obtained via an oscilloscope. To build this boost converter that meets the team specifications the team needs the power stage that will provide the 12V output from a 5 V input. To set the desired frequency for this converter we need to design a pulse width modulation (PWM) circuit up to 20 kHz to drive the boost converter. For PWM circuit we used a Power MOSFET.[5]

3.1 Theoretical values

To obtain the necessary boosting action, the 100 uH inductor was increased to a 122 uH. In order to eliminate noise at the output, all wire lengths were shortened. To eliminate noise from the ground plane, 47 uF capacitors were added to the input and the output of the circuit. The 1.68 uF capacitor was increased to 47uF, in order to decrease the output ripple.

4. Simulation Result

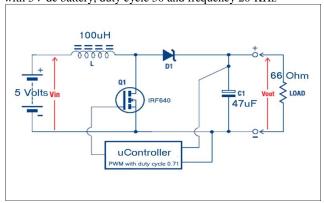Simulation of Boost Converter in MATLAB, Simulation with 5V dc battery, duty cycle 50 and frequency 20 KHz

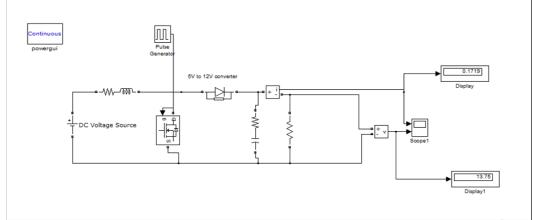**Fig.1**: Boost Converter Design Circuit

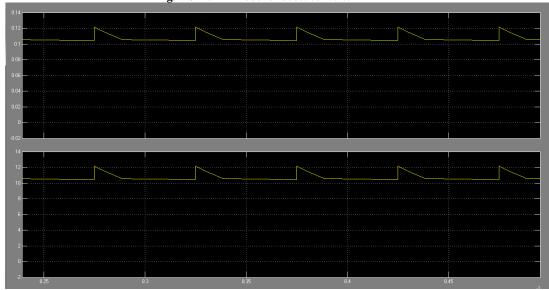**Fig.2**: Simulink model of boost converter

Fig. 3: Zoomed Output and Plots of Output Voltage and Current Waveform

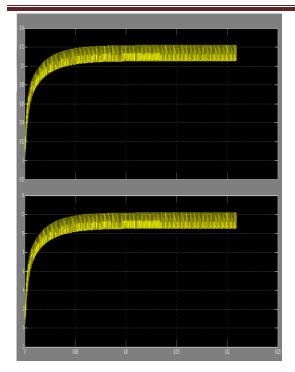**Fig.4** Experimental Output and Plots of Output Voltage

Fig.5: Output and Plots of Output Voltage and Current Waveform

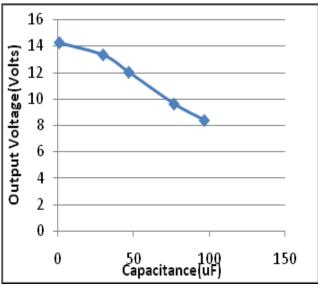**4.1 Variation in Output current and voltage with the Duty cycle, Inductance and Capacitance.**

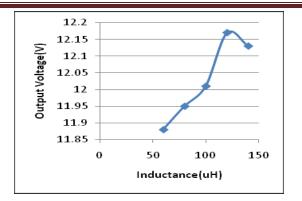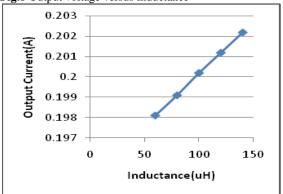**Fig.6** Output voltage versus capacitance

Fig.8 Output voltage versus inductance

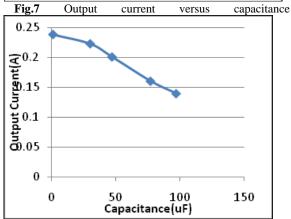**Fig.7**   Output   current   versus   capacitance

Fig.9 Output current versus inductance
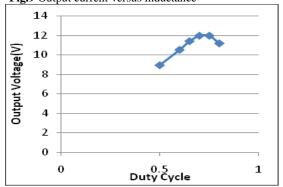

Fig.10 Output voltage versus duty cycle

Fig.11: Output current versus duty cycle

5. Result and Discussion

All of the specifications stated previously have been met by this boost converter design. The output voltage across the output capacitor is 12V with a maximum output ripple of 1.6%.The power efficiency of the circuit exceeds 80 % for the load range of 4-5W. However an additional constraint needs to be put on the load. The load must not exceed 5 W. Addition of Heat Sink was very important role as on Physical touch heat sink also gets hot. So it can damage the MOSFET without heat sink or a smaller heat sink. Use of electronic inductor is avoided due to low current carrying capacity. Value of the inductor should be 1.2 to 2.5 times more than the calculated value. Inductor core should be strictly locked so that there is no air gap.

As duty cycle increases output voltage and current increases to certain extent and then decreases as losses increase beyond that value duty cycle. With the increase in inductance the output voltage also increases to certain extent and then it decreases as losses increase beyond that value of inductance. For maximum efficiency voltage boosting should be 2 to 3.
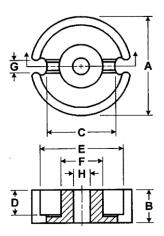
6. Conclusions

The average output voltage of the converter practically comes to be 11.2V as compared to the 13.75V form the Simulink. The efficiency of the converter comes out to be 80%. Practically there is a dip in output voltage waveform as compared to the Simulink output voltage waveform.

References

[1] 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.

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

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

[4] Dr. P.S. Bhimra. Power Electronics. Khanna publishers. New Delhi, India

Appendix

DIMENSIONS

	inches	mm		inches	mm
A	.709 ± .015	18 ± .381	2D	.284 min.	7.2 min.
B	.210 + .000 − .005	5.33 + .000 − .127	E	.590 min.	14.98 min.
2B	.420 + .000 − .010	10.67+ .000 − .254	F	.299 max.	7.59 max.
C	.515 nom.	13.08 nom.	G	.162 min.	4.1 min.
D	.142 min.	3.6 min.	H	.122 ± .003	3.10 ± .076

MAGNETIC DATA

MAGNETIC PATH LENGTH (cm)	2.59	CORE WEIGHT (grams per set)	7.3
EFFECTIVE AREA (cm²)	.429	Wa Ac ‡ (cm4)	.073
VOLUME (cm³)	1.11	‡ Product of window area & core area, 1 sec. standard bobbin.	

NOTE: Minimum core area .360 cm²

[5] Ramshaw, R.S. Power electronics, Thyrsitor controlled power for electric Motors' London: chapman & Hall ltd., 1982.

[6] Fairchild Semiconductor Reference Data Sheet: IRF840B.

[7] Muhammad H.Rashid 'Power Electronics Circuits, Devices and Application' third edition, Pearson Education, Inc.2004.