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Research Article

Designing and Implementing of 72V/150V Closed loop Boost Converter for Electoral Vehicle

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Abstract

Increased pollution and increased prices and consumption of liquid fuels led to the pursuit of alternatives that are not polluting and at the same time reducing costs and to be available. Of these clean energies are solar energy, wind energy and water flow. There are a lot of attempts that have been made in the world, so the subject of paper at the backbone of these attempts, which may be the first spark in Iraq to develop and launch towards a new horizon in this area. The main part of stages in electrical vehicle is the boost converter. This paper presents the designing and implementing of closed loop Boost converter for electrical vehicle. The closed loop boost converter is used to convert a dc input voltage from batteries bank to a high-level dc voltage required for the load. Closed loop technique is used To regulate the output voltage of the converter. The control depends on the feedback voltage which compared with a reference voltage. The amplifier will be control by fed amplifier signal turn on the 555. Hence will be control on MOSFET to keep the output to be constant. All this stage of the circuit is designed and implemented, the result for the boost converter obtained are presented in this paper.

Keywords: *Liquid fuels, Electoral Vehicle etc.*

Introduction

The DC to DC Switches Boost Converter is designing to providing an efficient way of taking the given the DC voltage supplied and to be boosting it to the desired value. With output voltage that be greater than source voltage. It is called in sometime the step up converter. In a boost converter, the switching can be using power Metal–Oxide–Semiconductor Field-Effect Transistor (MOSFT) [Kazimierczuk, M.K, 2015] is shown in Figure 1.

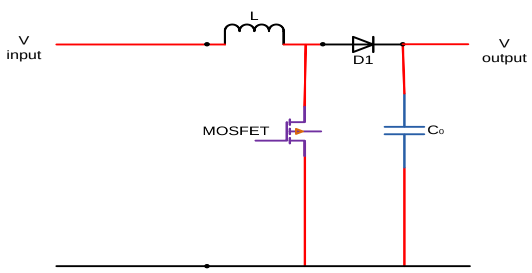

Figure 1 Basic Boost Converter Circuit

The DC-DC converter is used to convert non-regulated DC inputs to the required DC output by controlling the required voltage level. It generally conducts the conversion by applying the DC voltage via a inductance for a period of time (usually in the range of 20 kHz to 5 MHz [which causes the current through the flow and storage of the magnetic energy, then switching the voltage off and causing the stored energy to be transferred to the output voltage Controlled manner. The output voltage is regulated by adjusting the ratio of on / off time. This is achieved by using the switch mode, Pulse Width Modulation (PWM) allows controlling of the output voltage. Normally, the efficiency is usually obtained within range of 75% to 90%.

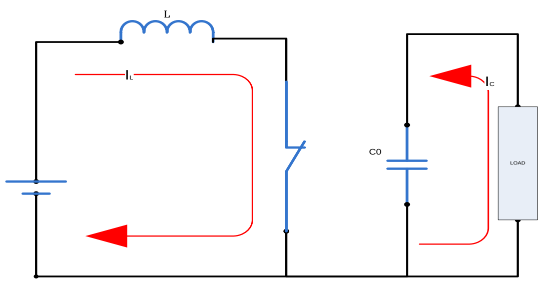

Figure 2: Equivalent circuit when switch is on.

The boost converter as shows in Figure 1 is operating in two state modes. Mode-1: When the switch is closed (in ON state), the circuit it will be two loops first loop at the output side and the second loop at the input side. The loop in the input of the inductor gets charged through the current flow through the loop during this

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period. This current will increase linearly until the switch time is in closed condition. At the same time interval, the inductor voltage is also high as it is not delivered to any load but for itself. The diode is out during this mode. Figure 2 shows the equivalent circuit representation of mode 1.

Mode-2: When the switch is in OFF state (Open), there will be a closed loop consisting of power source, inductor and RC load. The energy stored in the inductor during ON state is discharged to the RC load circuit through the diode. Thus inductor current is reducing linearly, charging the capacitor at the load side. The equivalent circuit for mode 2 is shown in Figure.3.

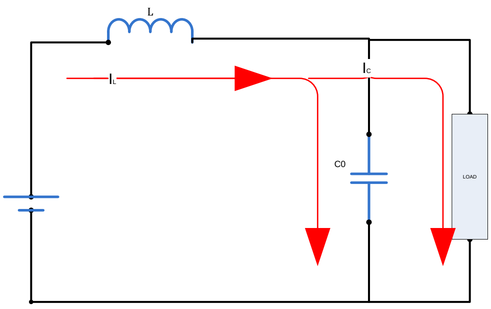

Figure 3: Equivalent circuit when switch is off.

Thus for closed switch time inductor gets charged and capacitor is delivering the required power to the load, and for the opened switch time inductor will discharge supplying the full power to load and charging capacitor simultaneously.

Load Requirement

The load is three phase induction motor through three phase inverter would require a current of 10-50 A and a minimum of 150 volts is required. Based on this load requirement the other parameters would be calculated and the specifications are tabulated in the following table.

Table I Specifications

Parameter	Value	Unit
Input voltage, Vin	67-78	Volts
Output voltage, Vout	150	Volts
Output current, Iout	50	A
Ripple, r	.0125	%

The theoretical calculation of the DC output voltage it will be coming by input voltage (V_i) divided by the duty cycle (D) of switching waveform, and the value of the duty cycle (D) between 0 and 1 (correspondingly from 0 to 100%) and so it can be determined by using the following equation [Choi, B.2013]:

$$\text{Duty cycle (D)} = 1 - \frac{V_i \times \eta}{V_o} \tag{1}$$

Where: Vi: Input voltage; Vo: Output voltage; η: efficiency and equal 0.75 to 0.95.

The load resistance:

$$\text{load resistance } (R_l) = \frac{V_o}{I_o} \tag{2}$$

The voltage ripple:

$$\text{Voltage ripple } (\Delta V) = \text{ESR } \times \left[\frac{I_o}{1-D} - \frac{\Delta I_{L_{new}}}{2}\right] \tag{3}$$

Where:

ESR: Equivalent Series resistance of used output capacitor

$\Delta I_{L_{new}}$: Inductor ripple current; I_o: output current

The capacitor formula:

$$\text{Capasitor } (C_o) = \frac{I_o \times D}{f_s \times \Delta V} \tag{4}$$

Where:

ΔV: Voltage ripple; f_s: Switching frequency of converter

Delta of the output current equal to 10% from the output current so:

$$\Delta I_o = 0.1 \times I_o \tag{5}$$

The coil formula:

$$L = \frac{V_s \times D}{f_s \times \Delta I_o} \tag{6}$$

Because the output voltage is dependent on the duty cycle, it is important that this is accurately controlled.

Designing of required circuits

The required components design to achieve the desire voltage and current as following below:

A. Design of comparator

As shown in Figure.4 can see the comparator circuit by using (op-Amp LM339), lets assume that the V_{ref} greater than V_{in} then the output will be - low the result will be at the negative supply voltage ($-V_{cc}$). if we increase the V_{in} till be greater than V_{ref} the result will be high at positive supply voltage (V_{cc}) [Robert Diffenderfer,2005].

$$V_{in} > V_{ref} \text{ then } V_{out} = V_{cc}$$
$$V_{in} < V_{ref} \text{ then } V_{out} = -V_{cc}$$

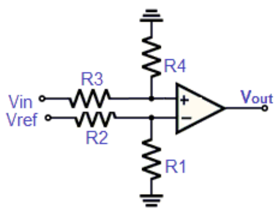

Figure 4: Comparator circuit by using LM339

B. Designing of PWM Generator [David E. Lalond, John A. Ross,1994] :

The output of differential amplifier is fed to 555 Timer which in turn generates PWM signal. The PWM signal required for switching action is with a frequency of 810 kHz and duty ratio of 62 percent. To generate a 62 percent duty cycle, the 555 , D1 between the trigger input and the discharge input, the timing capacitor would charge up directly through resistor R1 and R2.

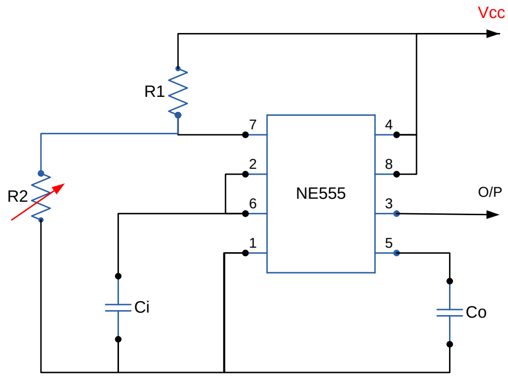

Figure 5: PWM generator circuit

C. Power amplifier for MOSFETs Gate

Figure (6) shows the amplifier circuit that used to amplified the output signal which was generated from 555, because the output voltage that generated by 555 will be less than 5v and it will not be enough to manage the on/off switching of 5 MOSFETs. In this circuit the switch that used is MOSFET IRF740 with resistance 5Kohm between emitter and ground. The output of the Amplifier will be 24v will divide on 5 MOSFETs so 4.8v will apply on each MOSFET through resistance 2Kohm.

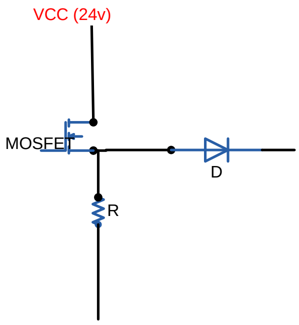

Figure 6: Power amplifier circuit

Choose of components for implementation

A. Choose of Electronic Switch (power MOSET)

It will be chosen based on current and voltage rating which must be higher than the input voltage and current. Therefor MOSFET-IRF630 will be suitable. The high power required (50A,150V) lead to using multi stages or using array of MOSFETs to decrease the stress than of using one MOSFET hence, as shows in Figure.7 five MOSFETs are used instead of one MOSFET, Each MOSFET(IRF630) will manage 10A to have 50A from all the MOSFETs and using 0.33ohm resistances series with collector of each MOSFETs to ensure that no over current will be happen.

B. Choose of Inductor

In equation (6) shows, the minimum inductance of the boost converter to be work in continuous connection mode. Therefore, the inductor selection must be higher than the calculated value. Figure.8 shows the inductor that will be used (36 turn, 1.5mm copper cable, 15mm dimeter of core).

C. Choose of Diode

The reverse diode voltage rating is the main consideration for diode selection. Another important consideration is its ability to prevent the required stress from off- state voltage and has sufficient capacity to handle peak and current average, fast switching characteristics, low reverse recovery, and low voltage drop forward.

D. Choose of Output Capacitor

The minimum capacitance is given in equation (4) to calculate the ripple voltage. Choose a capacitor higher than the calculated value. Another important consideration is its resistance to the equivalence series, ESR. Since the evaporator capacitor affects efficiency, low-evaporative capacitors can be used for optimal performance. ESR can be reduced by attaching a few capacitors in parallel.

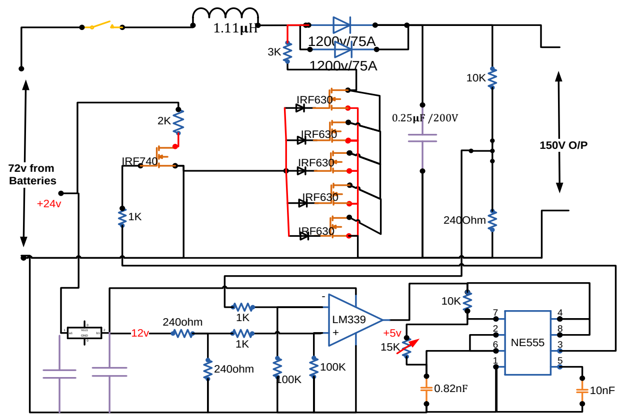

Figure 7: DC-DC concrete circuit with feedback control

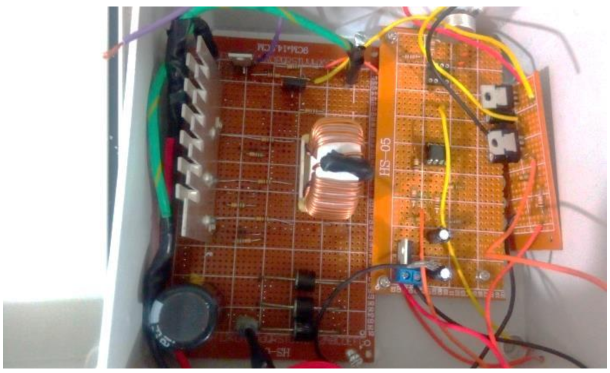

Figure 8: boost converter circuit

The DC / DC closed loop is designed to convert the inputs from the battery bank that is represented in the diagram. The output of the battery bank can vary from 67 to 78 volts. In order to regulate the output voltage for the difference in the closed-loop input technique the voltage feedback is used. Where the signal voltage is generated using a voltage divider in the output. 0.033 percent of the desired output is generated using the voltage divider and compared with the reference voltage. The voltage divider consists of two resistors. One resistor is 0.024% of the last one. Thus the output voltage for this resistor is 0.033% of the total load voltage. This voltage is compared with the reference voltage which should be 0.033% value of 150 A 5 V This output of the comparison will turn on the timer 555, thus generating a PWM of 62% working dury cycle. The output from the 555 timer is fed to the gate terminal of the power MOSET. This pulse in turn will control the gate of the MOSET based on the frequency. Here they are designed for frequency switching of 810 kHz. Thus when the pulse is at a high level the MOSET will be in saturation mode there by making the ON mode condition. When the pulse is low the MOSET will be in the cut-off mode thus making the switch open (switch-off condition). Whenever the input becomes low conversion the output becomes also low and the output of the comparator becomes positive and will keep output steady. When the input to the converter increases the output increases and the output of the comparison becomes negative and the MOSFET will off to be the output at the desired level. So the closed loop process regulates the output voltage against variations in input voltage ranging from 67 to 78 volts.

Discussion and Result

Analysis of the circuit is carried out based on the following assumptions. The circuit is ideal. It means when the switch is ON, the drop across it is zero and the current through it is zero when it is open. The diode has zero voltages drop in the conducting state and zero current in the reverse-bias mode. The time delays in switching on and off the switch and the diode are assumed to be negligible. The inductor and the capacitor are assumed to be lossless.

The responses in the circuit are periodic. It means especially that the inductor current is periodic. Its value at the start and end of a switching cycle is the same. The net increase in inductor current over a cycle is zero. If it is non-zero, it would mean that the average inductor current should either be gradually increasing or decreasing and then the inductor current is in a transient state and has not become periodic.

It is assumed that the switch is made ON and OFF at a fixed frequency and let the period corresponding to the switching frequency is T. Given that the duty cycle is D, the switch is on for a period equal to DT, and the switch is off for a time interval equal to (1 - D)T. The inductor current is continuous and is greater than zero. Here the triangular waveform is inductor current and square waveform is voltage across inductor.

The capacitor is relatively large. The RC time constant is so large, that the changes in capacitor voltage when the switch is ON or OFF can be neglected for calculating the change in inductor current and the average output voltage. The average output voltage is assumed to remain steady, excepting when the change in output voltage is calculated.

The output voltage comes constant to 148.5 volts for various levels of inputs and current is 50A. Whenever output voltage becomes more than 150 volts the comparator will generate a negative saturation level voltage signal and so output would come down to 150 volts. And when output becomes less than 150 volts the comparator will generate a +Vcc and thereby increasing the voltage to 150 volts. Hence the output voltage is keeping constant.

The hardware is tested at various levels for a given input voltage variation. The observed results in both hardware and software simulation are compared and shown in table below. The expected output is 150 volts and in software it is coming 148.5.6 volts while in hardware it is getting regulated to 147.2 volts.

Table 2 Boost Converter Output by using closed Loop

Vin	Vout (Simulation)	Vout (practically)
67	148.5	147.2
68	148.5	147.1
69	148.5	147.2
70	148.5	147.3
71	148.5	147.5
72	148.5	147.5
73	148.5	147.6
74	148.5	147.5
75	148.5	147.4
76	148.5	147.6
77	148.5	147.6
78	148.5	147.6

Figure 9 Output voltage from boost converter will be input to 3 phase inverter

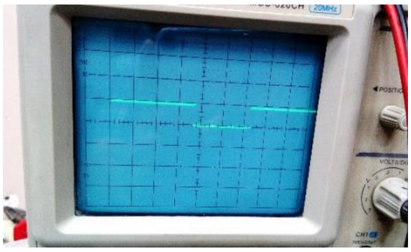

Figure 10 PWM signal 62% duty cycle

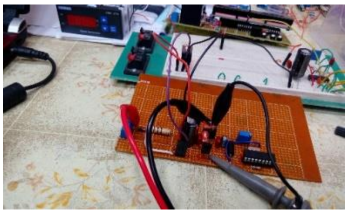

Figure 11: Oscillator circuit will generate 62% duty cycle.

Conclusion

In this paper can see simple circuit and cheapest with high performance from the test it shows the circuit was efficient and it can be sure the variation of the input will not affect about the output and the efficiency about 97% a low cost high performance DC-DC closed loop boost converter has been proposed.

A laboratory prototype board has been built and experimentally tested for the input voltage ranging from (67-78)V. For the specified input variation, a regulated dc output voltage of 148.5.V has been obtained resulting in an efficiency of 95%.

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