DESIGN OF 24 / 320 VOLTS BOOST-UP CHOPPER WITH MICROCONTROLLER BASED PI CONTROLLER

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Abstract — **This paper presents prototype of microcontroller based 24 V to 320 V DC Boost-up chopper with Proportional-Integral (PI) and Pulse Width Modulation (PWM) Controller. A Microcontroller is applied to generate PWM signals controlling duty cycle for switching Insulated Gate Bipolar Transistor (IGBT). PI control method is used to regulate the output voltage of the boost-up chopper to be more stable. Based on the simulation and prototype test results in the laboratory show that the prototype worked properly and able to produce a stable output voltage with a margin of error of 2.18% compared to target output voltage of 320 VDC.**

Keywords- Boost-Up Chopper, IGBT, Microcontroller, PI Controller and PWM.

I. INTRODUCTION

This paper proposes a prototype design of 24 V to 320 V DC boost-up chopper with Proportional-Integral (PI) and Pulse Width Modulations (PWM) control methods, which are used to control the DC output voltage of the boost-up chopper. A microcontroller is used to implement the main control component of the chopper circuits. The main advantage of using microcontroller is its programmable feature, making more flexible to modify the control action by modification of the microcontroller program.

II. RESEARCH METHOD

A. Prototype Design

Figure 1 Shows the block diagram of 24 V / 320 V DC Boost-up chopper with microcontreller based PI Controller.

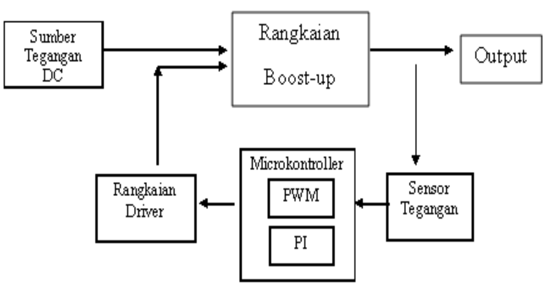


Figure 1. Boost-up chopper diagram

B. Boost-up Chopper Circuit

The boost-up chopper circuits consist of diode, inductor, capacitor and switching component as shown in Figure 2. On the interval when the switch (SW) is closed, the inductor is connected to negative terminal of DC power supply and the inductor's current increases. At the same time, the diode is backward biased causing no current flowing through the load. In this mode, the electrical energy is stored in the inductor. Then, when the switch (SW) is open, the output terminal will receive energy from the inductor and power supply [1],[2],[3],[4].

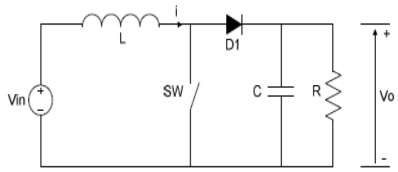


Figure 2 Boost-up chopper circuit [1], [4]

The overall system result is regulated DC voltage on the output side. Hence, boost-up chopper can increase output voltage without any transformers.

In this project, boost-up chopper circuit is designed to produce 320 V DC ouptut from input of 24 V DC using parameters as follow :

Input voltage (Vin)	= 24 Volt
Output voltage	= 320 Volt
Ripple voltage	= 1%
Switching frequency	= 28 kHz
Output current	= 3 Ampere

With above parameters, the components value of chopper circuits were set as follow :

Duty Cycle (D)	= 92.50%
Resistance value (R)	= 106,6 Ohm
Inductor (L), min	= 9.904 mH
Capacitor (C), min	= 33.48μF
$C_{snubber}$	= 2.5 nF
$R_{snubber}$	< 6607.14 Ohm

The snubber circuit is used to protect the circuits during the switching process of the chopper circuits.

C. PWM Generator

PWM Generator uses register counter on the Atmega 8 microcontroller to control the duty cycle value of circuit. Atmega 8 is 8 bit CMOS microcontroller with AVR RISC architecture and have 8K *byte in-System Programmable Flash*. This low power consumption microcontroller can execute instructions with maximum speed of 16MIPS on 16 MHz frequency.

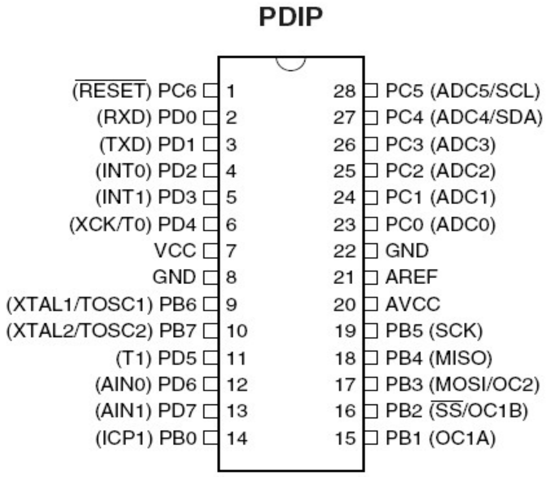


Figure 3 Atmega 8 pin configuration [5]

In this project, duty cycle is set on value of 237 from the total bit 256. PWM signal is then generated as ON and OFF function and used as the switching control signals of the IGBT devices which control the output voltage of the chopper. The ON and OFF state of the PWM signals are used as electronic control switch of IGBT or MOSFET which influence the voltage and current flow trough the load connected to the boost-up chopper.

D. *Optocoupler* dan *Totempole*

Optocouple is driver insolation circuit with control circuit. Totempole circuit is used to reduce switching losses during the switching process. This circuit is very important in receiving PWM signal from microcontroller to make the IGBT switches work. In this project IC TLP 250 (Figure 3), with optocoupler and totempole circuit inside is used.

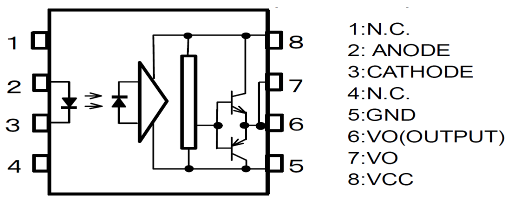


Figure 4. Configuration of TLP 250 [5]

E. *PI Controller*

The output voltage of the boost-up chopper that is sensed by voltage sensor will be used as feed-back of the controller. The output of boost-up chopper is controlled by PI controller. The value of PI parameters in this research are set using Trial and Correct method.

F. *Voltage Sensor Circuit*

Voltage sensor in the boost-up chopper circuit is used to sense the output voltage of the chopper, and its output is used to determine the operation of the control circuits. Figure 4 shows the circuit devider used as voltage sensor of the boost-up chopper.

III. COMPUTER SIMULATION TEST RESULTS

The boost-up chopper with parameters as listed above is simulated using PSIM software. Simulation circuits of 24V / 320 V boost-up chopper with PI controller is shown in Figure 5. The simulation results of the circuits are presented in the Figure 6.

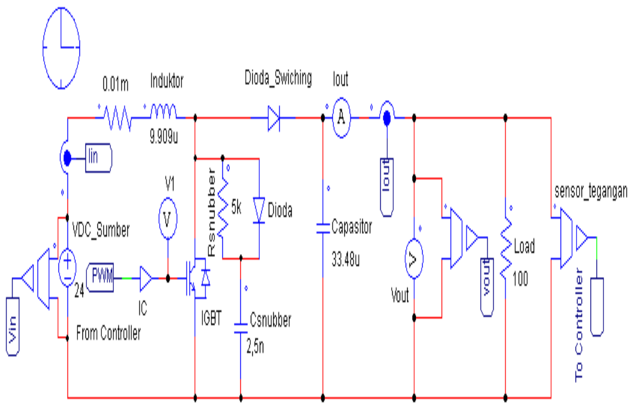
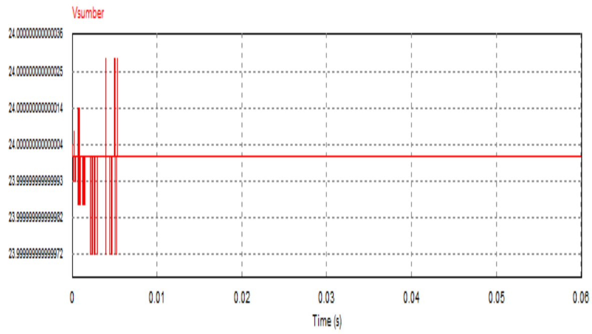
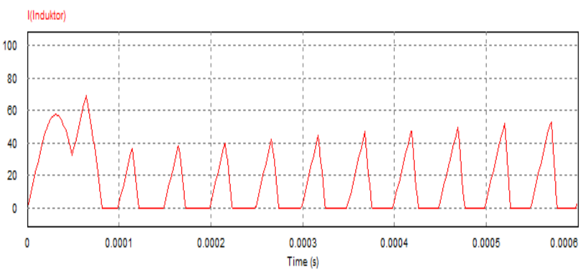


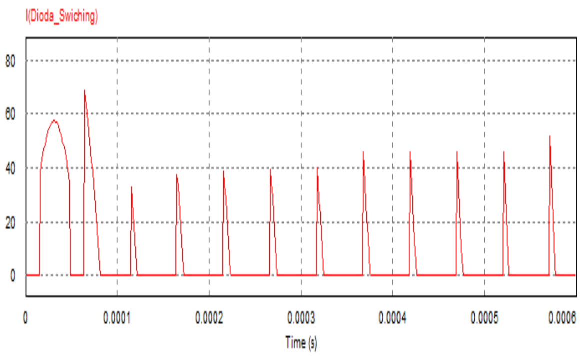
Figure 5. Boost-up chopper simulation circuit



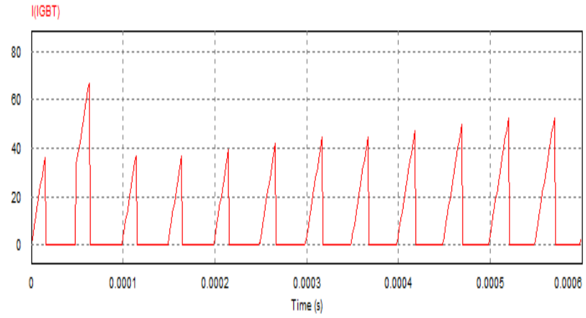
(a) DC Input voltage



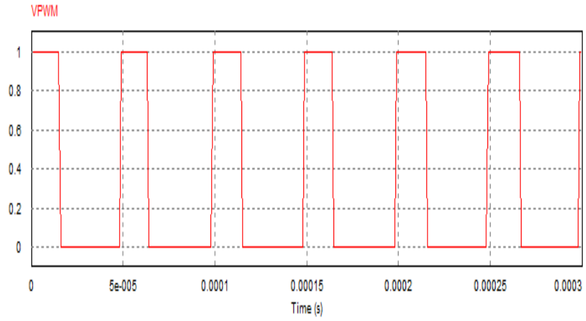
(b) Inductor current



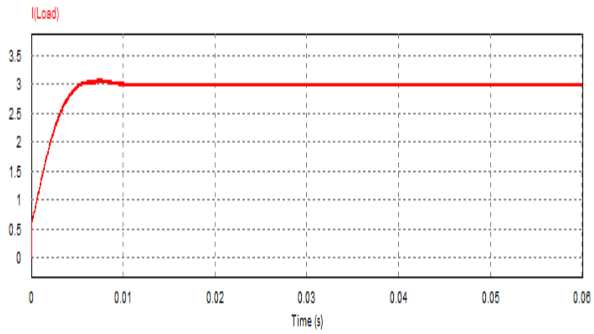
(c) Diode current



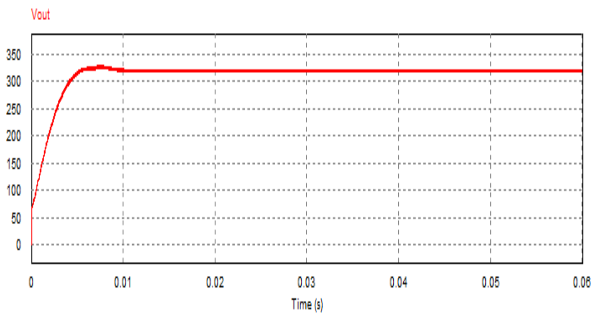
(d) IGBT Current



(e) PWM signal



(f) Load current



(g) output voltage

Figure 6. Computer simulation results of the Boost-up chopper circuits

As can be seen from the computer simulation results shown in Figure 6, the boost-up chopper works well generating higher DC output voltage from the 24 V DC input voltage. The measured output voltage (Vout) generated is 311 V_{DC}.

IV. EXPERIMENTAL TEST RESULTS

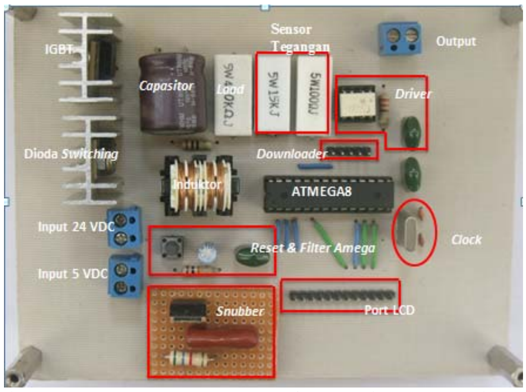
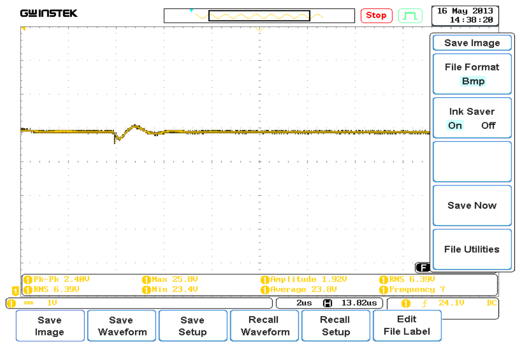
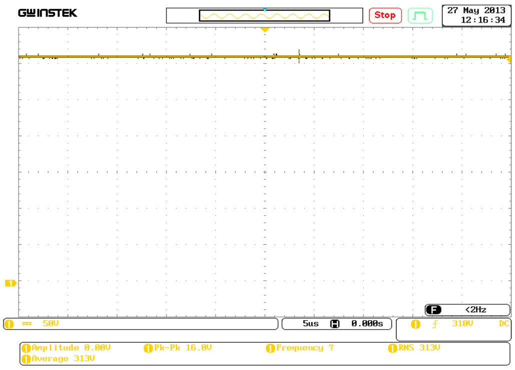


Figure 7. Prototype of 24 V / 320V boost-up chopper

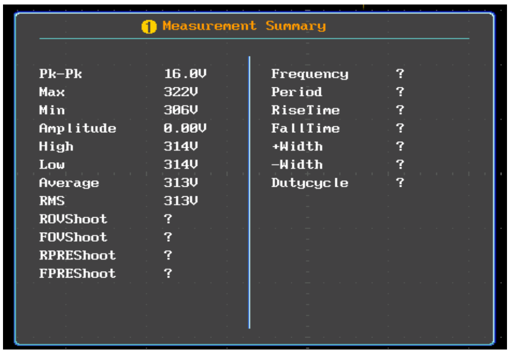
The boost-up chopper prototype have been implemented and tested in laboratory. Figure 7 shows the prototype. The prototype test is to evaluate the boost-up chopper, if it can produce output voltage of 320V as designed. The prototype test results is shown in Figure 8 bellow.



(a) 24 Volt input voltage



(b) Boost-up chopper output voltage



(c) Boost-up chopper test measurement

Figure 8. Boost-up chopper test results

The DC input source in the experiment was obtained from a laboratory DC power supply. From the measurement results using osciloscope, showed that the DC output voltage produced by the chopper circuits is 313 V (RMS). If compare with the design value of the chopper output voltage, 320 V, there is 2.18% difference or error. This error can be caused by the losses or voltage drops happening in the circuits. However, this error is relative small, it is bellow 5%.

V. CONCLUSIONS

This paper proposed a microcontroller based boost up chopper which can be utilize to step-up 24V DC voltage to be higher DC voltage, 320V. Based on the computer simulation and experimental test results can be concluded that the boost-up chopper worked properly because it can raise the voltage of 24V DC input voltage to be 320 V DC with a margin of error of 2.18%. The PWM signals waveform generated using ATmega8 microcontroller was applied to regulate the switching of the IGBT used in the chopper circuits.

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