Journal of Industrial Automation and Electrical Engineering
Vol. 01, No. 01, June, pp. 98~104

Design and implementation of buck-boost converter using Atmega 8535 microcontroller

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Article Info

Article history:

Received March 20, 2024
Revised May 10, 2024
Accepted June 19, 2024

Keywords:

Buck boost converter
Microcontroller
Atmega 8535
MOSFET
PWM

ABSTRACT

To achieve the desired DC voltage, a variety of DC-DC converter types are employed, including buck converters, which can generate output voltages lower than the input voltage, boost converters, which can generate output voltages higher than the input voltage, and buck-boost converters, which can raise and lower the output voltage value based on the input voltage value. MOSFET is used in this study's buck-boost converter design because to its lower cost. The Pulse Widening Technique, commonly known as the Pulse Width Modulation (PWM) approach, is one way to control the MOSFET modulation pulse. In designing the buck-boost converter using the ATMega8535 microcontroller, it consists of several main components, namely: The ATMega8535 microcontroller functions as a PWM signal generator, the MOSFET gate drive consists of an optocoupler 4N25 IC, which is used for switching the IRFP 250N MOSFET. In this study, a buck-boost converter will be made that can increase and decrease DC voltage. The output voltage setting of the buck-boost converter can be done by adjusting the power switch modulation pulse used in the buck-boost converter. The test results of the buck-boost converter circuit show that the converter can work well to increase and decrease the voltage according to the desired set point. Both in testing the tool with different loads and constant voltage, the tool is able to work as desired.

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1. INTRODUCTION

Generally, the electrical energy used by the community comes from the PLN network, which uses AC voltage. To obtain DC voltage, a power converter is needed that can convert AC voltage to DC voltage, which is also called a rectifier. To obtain the DC voltage value according to needs, it can be done by using a controlled rectifier or by adding a DC-DC converter that can regulate the DC output voltage according to needs [1]-[4]. To achieve the desired DC voltage, a variety of DC-DC converter types can be employed, including buck converters, which can generate an output voltage that is lower than the input voltage [5]-[10], boost converters, which can generate an output voltage that is higher than the input voltage [11]-[17], and buck-boost converters, which can generate an output voltage value that is both higher and lower than the input voltage value [18]-[33].

In this study, a buck boost converter will be made that can increase and decrease DC voltage. The output voltage regulation of the buck boost converter can be done by adjusting the power switch modulation pulse used in the buck boost converter. Generally, buck boost converters use fully controllable power switches, such as MOSFETs and IGBTs. In this study, the buck boost converter was designed using MOSFETs, because they are cheaper. One way to regulate the MOSFET modulation pulse is by using the Pulse Width Modulation (PWM) method, also known as the pulse widening technique. In this method, the

MOSFET conduction time is determined by the ON pulse width of the PWM. The PWM pulse width is determined by the duty cycle, which is the ratio of the ON time (Ton) to the switching period (T).

The PWM duty cycle setting for the buck boost converter power switch has been developed in several methods with various control devices by other researchers, such as the analog-based propositional method. In this method, the PWM duty cycle is set based on the results of the comparison between the reference output voltage and the measured output voltage. The PWM duty cycle value obtained is proportional to the voltage error resulting from the comparison. In addition, this proportional method has also been implemented using the STM32F334 microcontroller. One of the advantages of this method is that it is easy to implement. In addition to the Proportional method, the PWM duty cycle setting for the buck boost converter has also been implemented using the Proportional–Integral–Derivative (PID) method based on the Field-Programmable Gate Array (FPGA). The advantage of this PID method is that it is more accurate compared to the proportional controller, but it is difficult to implement, especially in determining the controller parameters. Based on the advantages and disadvantages of the control methods that have been applied by other researchers, this study designed the output voltage setting of the buck boost converter with the proportional method implemented with the Atmega AVR 8535 microcontroller. In addition to being easy to implement, another advantage of the buck boost converter made in this study is that it is cheaper compared to controllers using the STM32F334 microcontroller or controllers using FPGA. Because the price of the Atmega 8535 microcontroller is cheaper than FPGA or STM32F334. The buck boost converter made in this study is equipped with a keypad as a place to enter the reference output voltage value and an LCD as a screen to display the input and output voltages.

2. METHOD

Buck-boost converter is one of the dc-dc converters used to lower or increase DC voltage (Rashid, 2018). The main components of this buck-boost converter are the dc input voltage source, semiconductor switches in the form of MOSFET or IGBT, inductors, freewheel diodes, capacitors and resistor loads. Figure 1 shows the buck-boost converter circuit schematic.

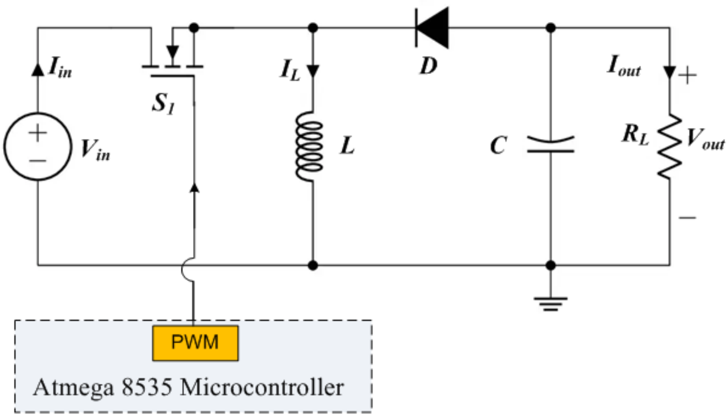


Figure 1. Buck Boost converter scheme

The PWM pulse determines the open and closed switch conditions. The diode will be reverse biased when connected, increasing the incoming current through the switch and inductor. When the switch is initially connected, the load does not get a voltage supply since the voltage on the capacitor is still zero. The diode becomes forward biased and transfers the inductor current to the load and capacitor when the switch is disconnected. The load will get the energy that the inductor has stored. The current in the inductor will decrease until the switch conducts again for the next cycle. When the switch conducts again, the current in the inductor will increase, and the energy stored in the capacitor will flow to the load, so that the voltage flow to the load will never be broken/continuous. The output voltage of this buck-boost converter can be greater or lower than the input voltage. The circuit will function as a boost if the duty cycle is greater than 0.5. The circuit will function as a buck if the duty cycle is less than 0.5. Output voltage of Buck boost converter can be formulated as follow :

$$V_{out} = -\frac{V_{in}}{(1-D)} V_{in} \tag{1}$$

where D is the duty cycle value of the PWM pulse that will modulate the semiconductor switch of the buck boost converter. The capacitor and inductor values of the buck boost converter are formulated as :

$$L = \frac{R_L \left(1 - D\right)^2}{2\, f_{sw}} \tag{2}$$

$$C = \frac{D\, V_{out}}{R_L\, f_{sw}\, \Delta V_{out}} \tag{3}$$

$$\Delta V_{out} = \frac{D\, V_{out}}{R_L\, f_{sw}\, C} \tag{4}$$

where f_{sw} is the switching frequency of the semiconductor switch of the buck boost converter. In this paper, a pulse modulated switch buck boost converter is designed using Atmega 8535 microcontroller. Figure 2 shows the block diagram of the proposed buck boost converter, which consists of Atmega 8535 microcontroller, voltage sensor, LCD, Keypad and power supply.

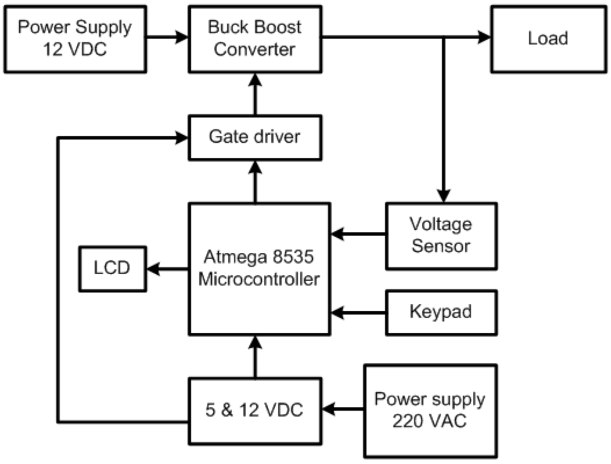


Figure 2. Diagram block of proposed buck boost converter

Figure 2 shows that there are several components used, namely 1) a power supply, which functions as a voltage supply for the MOSFET gate driver, and a 5-volt power supply, which functions as a voltage supply for the ATMega8535 microcontroller, voltage sensor, and LCD display. 2) The voltage sensor, in the form of a voltage divider, functions as a reader or detector of the output voltage from the buck-boost converter. The voltage sensor used is a voltage divider. 3) Buck-boost converter components that will increase and decrease the voltage according to needs, 4) ATMega8535 microcontroller, functions as a control center that will generate PWM signals for MOSFET switching, 5) MOSFET Gate Driver for isolation and protection of power and control circuits, 6) Keypad for input of output reference voltage, and 7) LCD display as a system output data viewer.

The overall working principle of the tool is regulated and controlled by the minimum ATMega8535 system as the main control and Basic Compiler (BASCOM-AVR) as its programming language. This buck-boost converter will work with an input voltage of 12 volts and with varying output voltages. In this case, the unstable DC voltage will be processed into a stable DC voltage through the buck-boost converter circuit. The voltage sensor functions as an output voltage detector that will appear on the LCD. Figure 3 shows the buck boost hardware circuit schematic created in this paper. The circuit consists of the main buck boost converter circuit, gate driver circuit, microcontroller circuit, LDC circuit, Keypad and sensor. This power supply circuit has two outputs: 5 volts is used as a voltage source for the ATmega8535 minimum system circuit, current and voltage sensors, and LCD, while the 12V output power supply is used to supply the MOSFET gate driver. The gate driver circuit is designed using the IR21845 IC. The LCD circuit does not have additional components because the microcontroller can provide data directly to the LCD; on the Hitachi LMB162A LCD, there is already a driver to regulate the scanning process on the LCD screen. For the LCD display is connected to PORT C on the microcontroller.

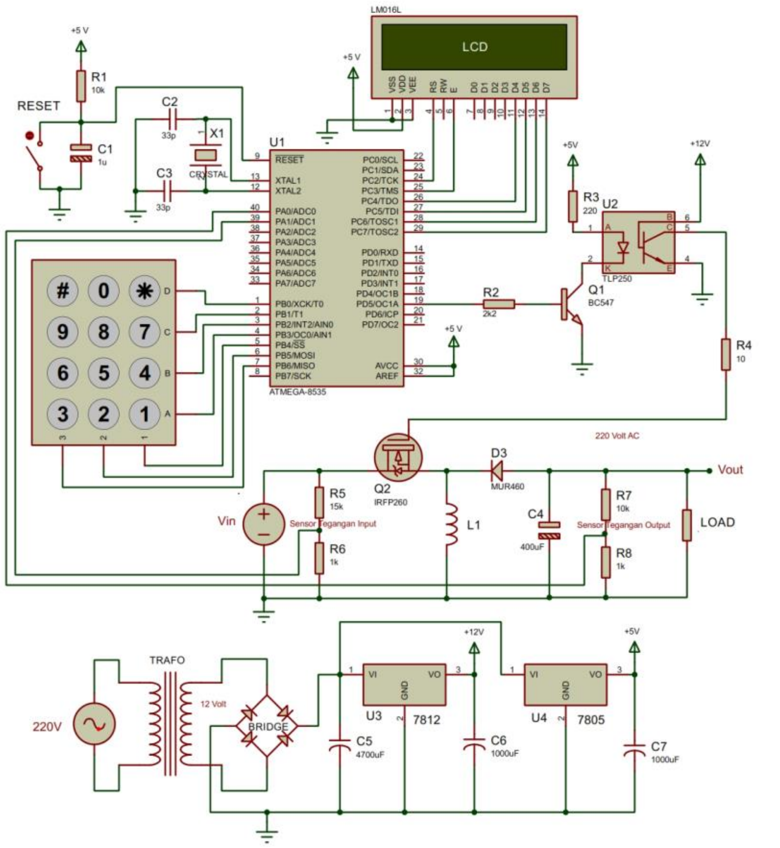


Figure 3. Circuit of proposed buck boost converter

3. RESULTS AND DISCUSSION

All components of the buck-boost converter circuit illustrated in Figure 3 are assembled and placed in a box. The circuit components are arranged in the box, while the keypad, input, and output terminals are placed on top of the box. The LCD that will display the input and output voltage data is placed on the side wall of the box. Figure 4 shows the results of assembling the buck boost converter hardware..

(a) (b)

Figure 4. Hardware of proposed buck boost converter,
(a) component placement inside the box, (b) The keypad is positioned above the box.

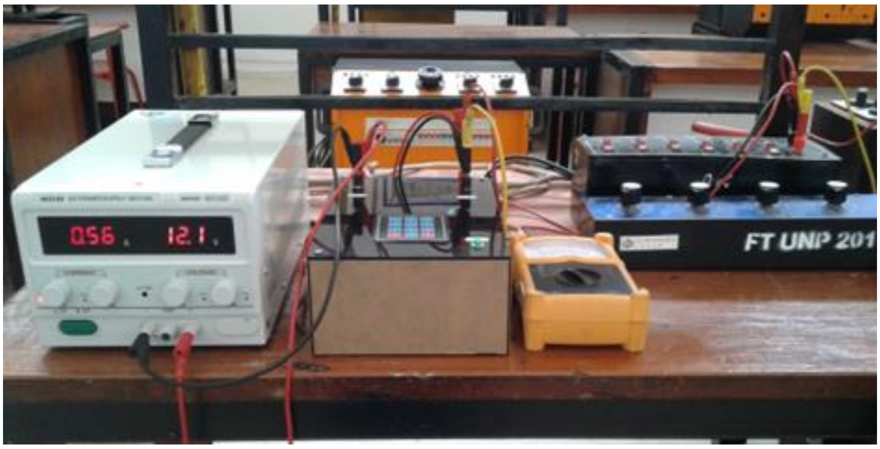
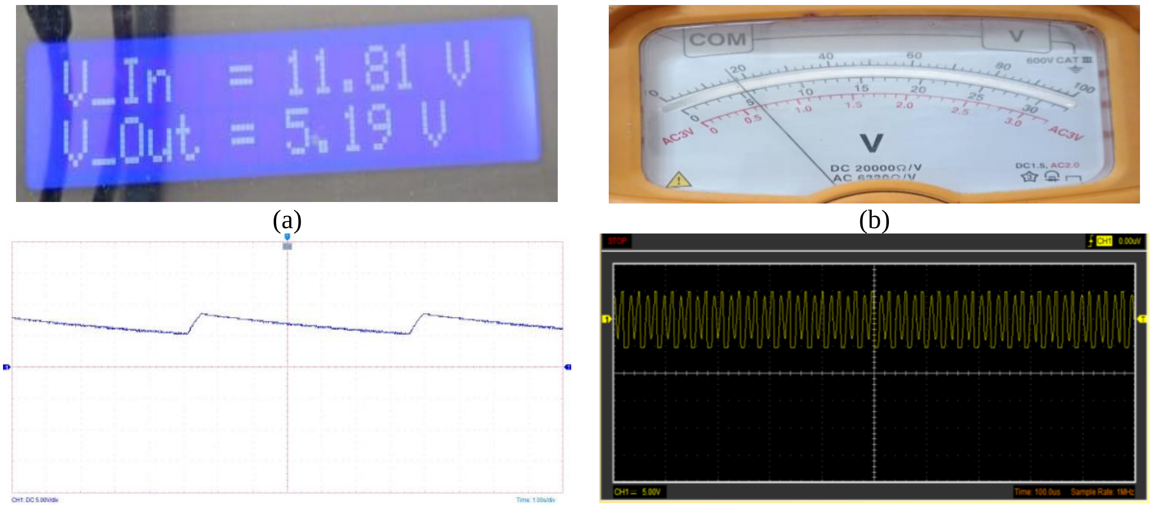


Figure 5. Experimental setup

The buck-boost converter suggested in this paper is tested under a variety of circumstances once all the parts have been put together. The hardware setup for the experiment is depicted in Figure 5. The buck-boost converter was tested with an input voltage of 12 volts, as shown by the LCD display in Figure 6(a). The first test was carried out for buck conditions with an output voltage lower than the input voltage, which is 5 volts. Figure 6 shows the results of the experiment.



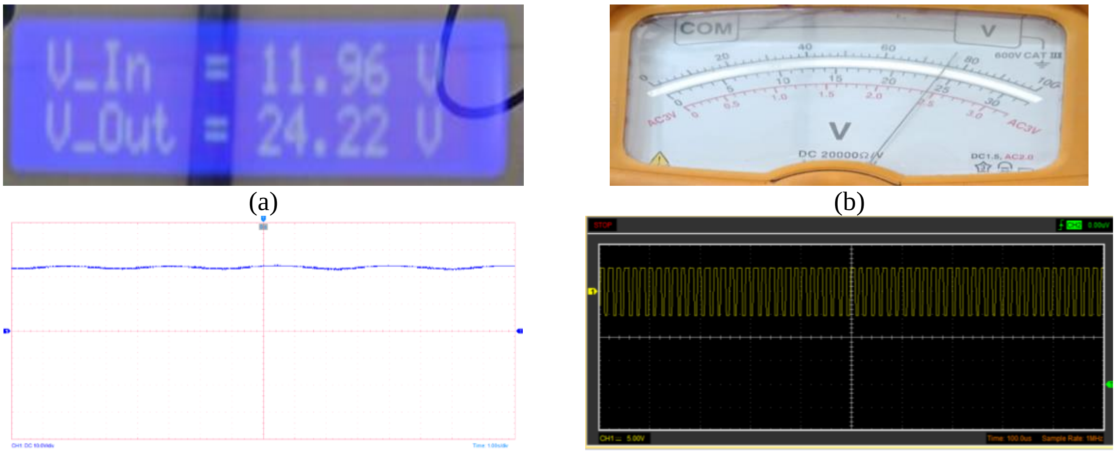
(a) (b)

(c) (d)

Figure 6. Experimental results with input voltage 12 Volt and output voltage 5 Volt, (a) LCD, (b) Voltmeter, (c) Output voltage waveform in Osciloscope, (d) PWM waveform at gate driver

Figure 6(a) shows that the input voltage read by the LCD is 11.81 Volts, while the output voltage read is 5.19 Volts. This value is close to the same as the reference output voltage inputted on the keypad, which is 5 volts. The same result is also shown by the voltmeter reading illustrated by Figure 6(b), where the Voltmeter reads an output voltage of 5 Volts. Figure 6(c) shows the voltage graph displayed by the oscilloscope, which value is also the same as that displayed by the voltmeter. Figure 6(d) shows the PWM pulse measured at the gate driver output terminal. The results of this first test show that the buck boost converter can work well for buck operations.

The second test was conducted for boost operation, where the output voltage of the converter was set higher than the input voltage, which was 24 Volts. Figure 7 shows the results of the experiment. Figure 7(a) and Figure 7(b) show that the output voltage of the measurement results from the LCD and voltmeter are close to the same as the setpoint voltage inputted on the keypad. These results indicate that the buck boost converter that was made has also worked well for boost operation.



(a) (b)

(c) (d)

Figure 7. Experimental results with output voltage 24 Volt, (a) LCD, (b) Voltmeter, (c) Output voltage waveform in Osciloscope, (d) PWM waveform at gate driver

4. CONCLUSION

This paper proposes a buck boost converter controlled by an Atmega 8535 microcontroller. The converter is designed with an input voltage of 12 Volts. Based on the results of testing and analysis of the buck boost converter circuit, it can be concluded that: The buck boost converter circuit can work well to increase and decrease the voltage according to the desired set point.

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