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Implementation of buck-boost converter as low voltage stabilizer at 15 V

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ABSTRACT

This paper presents the implementation of the buck-boost converter design which is a power electronics application that can stabilize voltage, even though the input voltage changes. Regulator to stabilize the voltage using PWM pulse that triger pin 2 on XL6009. In this design of buck-boost converter is implemented using the XL6009, LM7815 and TIP2955. LM7815 as output voltage regulator at 15V with 1A output current, while TIP2955 is able to overcome output current up to 5A. When the LM7815 and TIP2955 are connected in parallel, the converter can increase the output current to 6A. Testing is done using varied voltage sources that can be set. The results obtained from this design can be applied to PV (Photovoltaic) and WP (Wind Power), with changes in input voltage between 3-21V dc can produce output voltage 15V.

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1. INTRODUCTION

Economic growth and industrial development in all parts of the world are very rapid, resulting in increasing demands for energy use. Fossil energy currently still controls the main energy sources in the world, while renewable energy only contributes a small part of the world energy market [1]. Heavy reliance on fossil fuel energy causes the energy crisis provided dwindling and cause damage to the environment. One solution is to develop technology to harvest alternative energy such as energy from sunlight and wind efficiently and economically. One of the developments in the field of electronic applications is a converter. Simulation, modeling and analysis of the converter is in demand by researchers to be developed, so that the utilization of renewable energy is increasing.

DC-DC converters with the right selection of Kp and Ki values and implemented on PV network systems for interconnection with inverters can help to achieve a stable neutral current and a balanced load current. This converter implementation can reduce low costs, because it uses fewer components when compared to APF techniques [2]. Converters based on active and passive network inductors with dc-dc voltage gain can work on duty cycles (D) less than 0.5. This model is very suitable for extreme voltage ain [3]. Various converter topologies applied to PV can be used as a DC voltage source that is quite stable, but each converter has weaknesses and advantages. Buck-boost converter with integrated PV systems can generate the optimal output voltage [4]. DC-DC converter control based on LMI and control approaches with LQR is simulated to determine optimal performance. The simulation results show that, LMI-based control can overcome uncertain dc-dc converter conditions, while the control with LQR can only overcome the converter in normal conditions [5]. Many researchers have made observations about converters, but have not been able to overcome voltage fluctuations from DC sources that can change from photovoltaic and wind power at any time, so a converter design that can overcome source voltage changes is not constant.

Modeling and simulation of a boost converter with PI and FOPID controllers that are applied to PV. The results of the analysis of the two controllers provide a difference, where the control with FOPID is better than the PI control system [6]. Simulation and analysis-based voltage SEPIC converter for closed-loop circuit system in resonance with the induction of PI and FL control can reduce the source current THD of 4.98% to 3.48%, where control of the FL better when compared with PI control [7]. Simulation of buck-boost converters with chaotic control of dc-dc current mode can improve converter performance from periodic enzymes to chaotic regimes when reference currents vary from 2.65A to 3A [8]. Boost converter designed based on parameters that have been determined. Modeling using the MPPT control algorithm with PWM pulses is used as a trigger in the converter. With MPPT techniques can help in determining the maximum power point of PV and the results will be better when compared to without MPPT [9]. Simulation and modeling of converters has been carried out by previous researchers, but improvements are still needed to the fluctuating voltage source. In this paper provides an alternative solution to overcome the above using XL6009 with PWM pulses as a trigger to do the work of a converter that can stabilize the output voltage from a fluctuating voltage source.

The realization of a constant current charging system using a boost converter can produce 7.3A. Implementation of this boost converter in Lithium ion batteries and other types of batteries. Lithium ion battery charging takes time faster than other types of batteries [9]. The buck-boost converter has been used to charge batteries with different capacities in batteries of 12V, 7Ah and 12V, 120Ah. The results obtained that the percentage increase in charging current is different, for a 12V battery, 7Ah the percentage increase is 21.5%, while for a 12V battery, 120Ah the percentage increase in charging current is 10.99% [10]. The implementation of the converter in this work has been carried out using LM7815 to make the output voltage stable according to the requirements in charging the 12V battery, while as a voltage riser and use a combination of XL6009, TIP2955 and inductor. The proposed worksheet in this paper is to provide a solution in improving the performance of the buck boost converter, so that it can work on voltages that fluctuate from 3-21V DC.

2. RESEARCH METHOD

To find out the working concept or implementation of the proposed converter is shown in the framework in Figure 1. In the framework shown per section of the paper proposed is a buck boost converter design that has been verified and is equipped with the size of the components used in the converter. After that the results of the design are installed into the PCB for use in trials. The results of the proposed converter are plotted in a graph so that the relationship between changes in the input voltage and the output voltage of the converter can be determined.

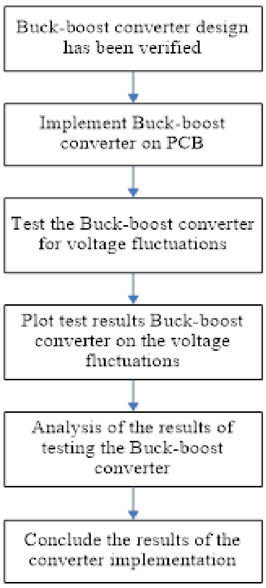

Figure 1. Framework of the buck-boost converter implementation

In this study is a combination of the XL6009 base circuit that has been modified to get a new model, so that it can be used in sources from PV and WP. Component components that are used are the results of previous designs that have been laboratory tests.

Figure 2 is a basic series of buck-boost converters used in research. The working concept of this circuit will increase the voltage and reduce the voltage according to the voltage to be charged as a battery charger. The function of each component, where XL6009 works when the input voltage is smaller than the output voltage, while the LM7815 functions to produce a voltage of 15V. The function of the duty cycle (D) as an increase and decrease in voltage with varying frequency changes. PWM pulses are arranged in such a way that they can function to regulate frequency changes in two conditions, namely 'Active' at 15.38kHz with a period of 65µs and 'Off' at 200kHz with a period of 5µs.

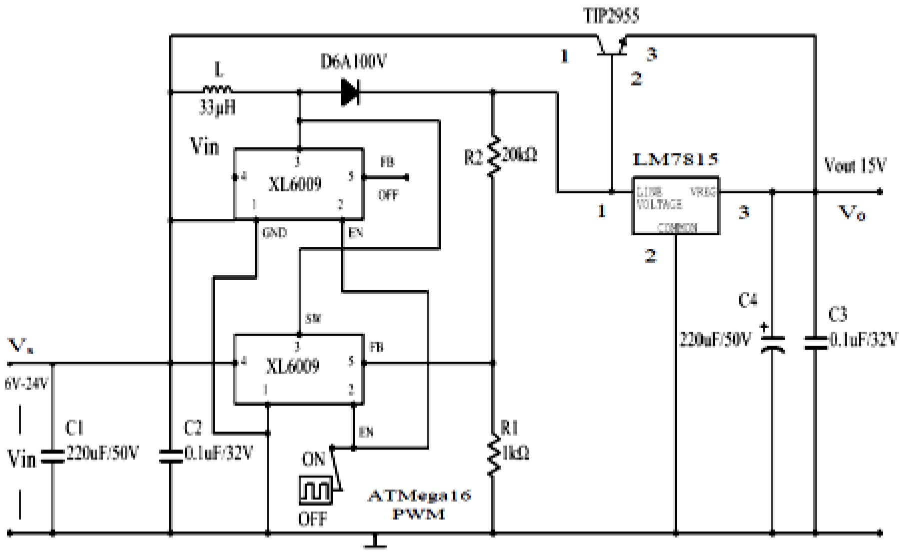

Figure 2. Basic circuit of buck-boost converter

Capability of LM7815 can only passing a current of 1 A, if the current into the buck-boost converter exceeds the current of LM7815, then TIP2955 will be served to take over current that exceeds capability of the LM7815, so the ability of the design of buck-boost converter can increase power by maximum current of about 6 A. Design buck-boost converter of this research capable only passed by a maximum current of 6 A, if the converter this used at greater than the current maximum, it is necessary to additions TIP2955 in parallel with the existing TIP2955. The buck-boost converter in the proposed research shown on Figure 3 shows the circuit of a buck-boost converter with component soldered on the PCB.

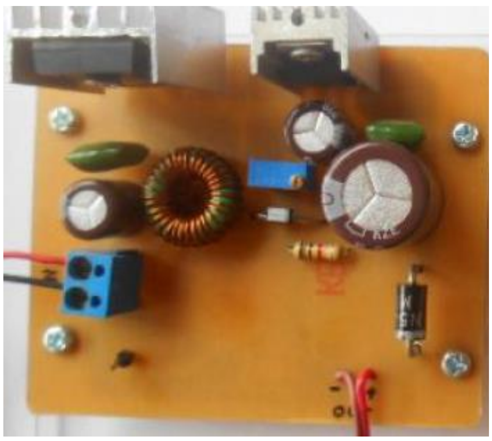

Figure 3. Component layout on PCB

The buck-boost converter plays an important role to provide a stable output voltage to maintain the voltage needed to charge a 12V battery. The voltage needed to charge a 12V battery must be greater than the battery voltage between 13-15V.

Designing of circuit involving various stages. The circuit design starts determining the specifications of the buck-boost converter as shown below.

$V_{i(min)}$ = 6V
$V_{i(max)}$ = 24V
V_{Ref} = 1.25V
V_o = 15V (LM7815)
Frequency switch = 15.385 Khz (‘On’ condition) and 200 Khz (‘Off’ condition)
Time Period = 5 μs (On condition) and 65 μs (Off condition)

Determine the duty cycle (D) as:

$$D = 1 - \frac{V_{in(\min)}}{V_0} \quad (1)$$

Duty cycle waveform such as Figure 4.

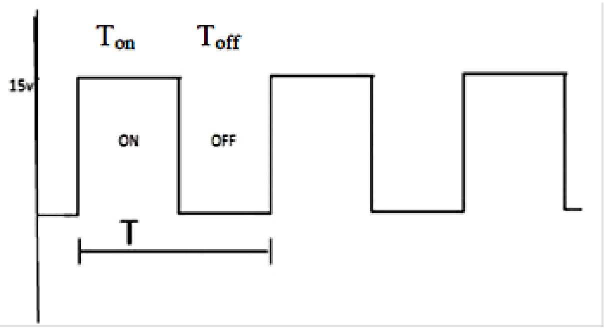

Figure 4. Waveform of duty cycle

Value of inductor(L) as:

$$L_{\min} = \frac{1}{f}(V_o + V_f - V_{i(\min)})(\frac{V_{i(\min)}}{V_o + V_f})(\frac{1}{\Delta IL}) \quad (2)$$

ΔI_L is ripple current of the inductors as:

$$\Delta I_L = 0.4 I_o (\frac{V_o + V_f}{V_{i(\min)}}) \quad (3)$$

Determining value of the capacitor(C) as:

$$C = \left(\frac{V_o . D}{R_i . \Delta V_o . f} \right) \quad (4)$$

R_i is input resistance given as:

$$R_i = \left(\frac{V_o}{I_o} \right) \quad (5)$$

ΔVo is the ripple voltage on the inductor as:

$$\Delta V_o = \left(\frac{V_o . D}{(V_{i(\min)} . R_i)^2 . f} \right) \quad (6)$$

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Determine the maximum input voltage with 2 setting resistors as:

$$V_i = V_{ref} \left(1 + \frac{R2}{R1} \right) \quad (7)$$

Where: V_{ref} is 1.25V.

$$V_i = 1.25 \left(1 + \frac{R2}{R1} \right) \quad (8)$$

The current rating of the circuit can be increased in order to handle larger current by mean of a TIP2955 in parallel with the circuit. The proposed circuit is a combination of XL6009 and TIP2955 to increase the output current of this converter.

3. RESULTS AND ANALYSIS

3.1. Result

The proposed buck-boost converter design uses a combination of XL6009, TIP2955, LM7815 and other components as shown in Figure 2, where XL6009 is used using PWM pulses on Pin 2 which functions as a buck or boost converter. The test results on the output side of XL6009 are shown in Figure 5, and the test results on the output side of the LM7815 are shown in Figure 6. In Figure 5, shows that the output voltage of XL6009 has not been stable, but has shown the voltage is greater than the input voltage, while in Figure 6, shows that the output voltage of the LM7815 has been stable at 15V.

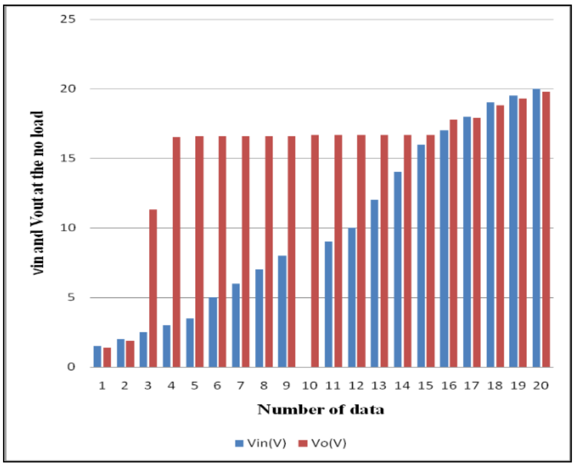

Figure 5. Output voltage of XL6009

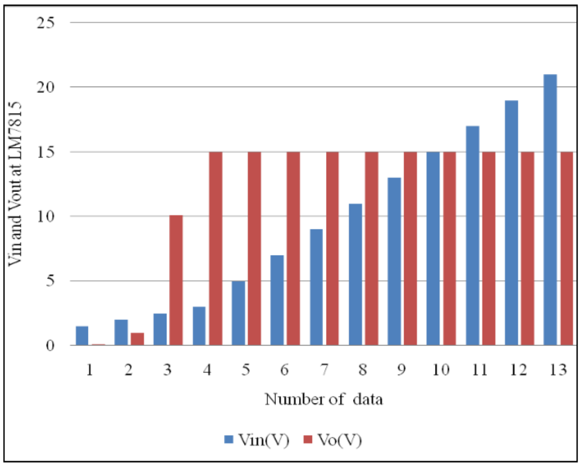

Figure 6. Output voltage after LM7815

3.2. Analysis

To determine the amount of the components used in the design of the parameters are as follows:

$Vi_{(min)}$ = 6V
$Vi_{(max)}$ = 24V
V_{ref} = 1,25V
Vo = 15V
I_C = 2,5A

Determine the duty cycle (D) as:

$$D = 1 - \frac{V_{in(\min)}}{V_0} \quad (9)$$

$$D = 1 - \frac{6V}{15V} = 0.6 \quad (10)$$

Determine the value of inductor based as:

$$L = 10.L_{\min} \quad (11)$$

(10 = Inductor value constant of tolerance)

$$L_{\min} = \frac{1}{f}\left(V_o + V_f - V_{i(\min)}\right)\left(\frac{V_{i(\min)}}{V_o + V_f}\right)\left(\frac{1}{\Delta IL}\right) \quad (12)$$

V_f=0.7 V (reference silicon components)

$$\Delta I_L = 0.4 I_o\left(\frac{V_o + V_f}{V_{i(\min)}}\right) \quad (13)$$

$$\Delta I_L = (0.4).(2.5)\left(\frac{15 + 0.7}{6}\right) = 2.61\,A \quad (14)$$

$$L_{\min} = \frac{1}{40}(15 + 0.7 - 6)\left(\frac{6}{15 + 0.7}\right)\left(\frac{1}{2.61}\right) = 0.0355H = 35.5\mu H \quad (15)$$

$$L = (10)x(35.5\ \mu H) = 355\mu H \quad (16)$$

Determining the value of the input resistance (R_i) as:

$$R_i = \left(\frac{V_o}{I_o}\right) \quad (17)$$

$$R_i = \frac{15}{2.5} = 6\Omega \quad (18)$$

ΔV_o is ripple voltage on the inductor as:

$$\Delta V_o = \left(\frac{V_o . D}{(V_{i(\min)} . R_i)^2 . f}\right) \quad (19)$$

$$\Delta V_0 = \left(\frac{(15)(0.6)}{((6)(6))^2(40)}\right) = 0.00017V \quad (20)$$

Determining the value of the output capacitor (C) as:

$$C = \left(\frac{V_o . D}{R_i . \Delta V_o . f}\right) \quad (21)$$

$$C = \frac{(15)(0.6)}{(6)(0.00017)(40)} = 220.6\,\mu F \quad (22)$$

Determining of V_i with two resistors settings as:

$$V_i = V_{ref}\left(1 + \frac{R2}{R1}\right) \quad (23)$$

$$V_{ref} = 1.25\ \text{V}. \quad (24)$$

$$V_i = 1.25\left(1 + \frac{R2}{R1}\right) \quad (25)$$

$$V_i = 1.25\left(1 + \frac{20k\Omega}{1k\Omega}\right) = 26.25V \quad (26)$$

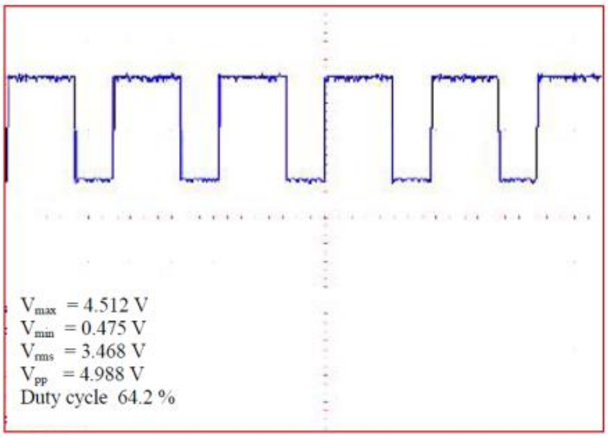

Figure 7. Duty cycle (D) from measurements buck-boost converter design

From the results of calculations and measurements of buck-boost converter design is obtained as: For the duty cycle (D) where the calculation results are 0.6, and the measurement is 0.642. There are differences between the two conditions, namely 0.042, but very small. For Inductors (L) where the calculation results are 35.5-355µH, and used is 33µH. In selecting an inductor, the researcher chooses an existing one from the manufacturer. For capacitors (C) where the calculation results are 220.6µF, and is used at 220µF, this will only affect the riple voltage used in this converter.

4. CONCLUSION

Based on the analysis of the design of buck-boost converter is obtained magnitude parameters are parameters: duty cycle (D) 0.6, the minimum inductor 35.5 µH, capacitor 220.6 µF and a maximum input voltage of 26.25V. The results of the analysis of the design is implemented using a combination of components XL6009, inductors 33 µH and capacitors 220 µF are capable of increasing and decreasing output voltage. The results of the design and implementation of the buck-boost converter can work well as a step-up and step-down the voltage.

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