A DC to DC Step-up Converter with IC LT 1615

Cekmas Cekdin
Department of Electrical Engineering
Muhammadiyah University
Palembang, Indonesia
email : cekmas_cekdin@yahoo.com

Zainuddin Nawawi
Department of Electrical Engineering
Sriwijaya University
Palembang, Indonesia
email : nawawi_z@ unsri.ac.id

Muhammad Faizal
Faculty of Engineering
Sriwijaya University
Palembang, Indonesia
email : faizal_ga58@ yahoo.com

***Abstract*-The circuit to increase the dc to dc voltage is the one that can increase the small input voltage to a large output voltage. This circuit is also called a step-up dc to dc converter circuit. The most important thing of this circuit is IC LT 1615 which is a micro power step up dc to dc converter in which the input voltage starts from 1 Volt to 6 Volts and the output voltage is from 7 Volts to a maximum of 35 Volts. The design of this circuit is intended to increase the output voltage of the thermoelectric generator (TEG) by 5 volts, which becomes the input voltage of the circuit of step-up dc to dc converter. Then the voltage is increased up to 30 Volts as the output voltage of the circuit. This circuit is used in TEG application for electricity generation.**

Keywords-DC to DC Step-Up Converter, IC LT 1615, Micro Power Step-Up DC to DC Converter.

I. INTRODUCTION

In a power supply system, it often occurs that input voltage is too small to operate an electronic device, so that the electronic device cannot operate perfectly. In this case, for example, the output voltage of the thermoelectric generator (TEG) cannot charge the battery or cannot operate certain equipment, thus disrupts the operation of the system.

To overcome this problem, a circuit that can increase dc voltage and regulate the current is created to fit the need of the system to be operated. This designed circuit produces the desired input and output voltage. It also fits the current needed. The design of this circuit is used in the application of TEG for power generation [1]. The circuit will increase the output voltage of the thermoelectric generator (TEG) of 5 Volts, as the input voltage in the step-up circuit dc to dc converter [2-3]. Then the voltage is increased up to 30 Volts as the output voltage of the circuit. This circuit is used in TEG applications for electricity generation. This circuit is a modification of that of Peter K et al., in 2012 [3], with voltage of (100-300 mili Volt) and a maximum output of 3 Volts. While that of the modified version results in 2 Volts of the input voltage and 30 Volt of output. So far, the process of increasing the dc voltage in the electronic devices has been too complicated, starting from increasing a smaller input voltage to become a larger output voltage through a transformer equipment. The output voltage of this transformer is in the form of an ac voltage. In order for the output voltage of this transformer to become a dc voltage, it must be rectified through a rectifier circuit, and this process is complicated.

By the circuit of step-up dc to dc converter, designed by Peter K *et al*, the input voltage in the form of dc voltage is directly raised to become the output voltage in the form of dc voltage as well, making the process less complicated. However, there is a problem with the design of Peter K *et al*, namely the input voltage is still very small (100-300 milli Volt), while the maximum output voltage is 3 Volts. Through the modification of the design of Peter K *et al*, the author can increase the 2 Volt input voltage and 30 Volt output voltage with IC LT 1615. The increase of incoming voltage 2 Volts and outgoing voltage 30 Volts was applied to the design of TEG application for Electrical Generation (Fig. 1).

The design of TEG application with incoming and outgoing voltage below or above 2 Volts and 30 Volts needs the different IC as shown in references [4-5]. Then the components of resistor, inductor, capasitor and diode are also adjusted with IC used.

II. RESEARCH METHODS

A. Literature Study

The voltage generated by the two sides of the copper connector namely 5 Volts on the thermoelectric in box 1 will be raised by a step-up dc to dc converter circuit in box 2 in Fig. 1. The input voltage V_{in} will always be smaller than that of the V_{out} ($V_{in} < V_{out}$). This circuit is also called a step up I circuit. Because the input is a dc voltage (V_{in}) and the output is also a dc voltage (V_{out}) this circuit is called A Step Up DC To DC Converter. The most important thing of this circuit is IC LT 1615 which is a micro power Step Up DC To DC Converter in which the input voltage begins from 1 Volt up to 6 Volts and the output voltage can be from 7 Volts to a maximum of 35 Volts. IC LT 1615 has 5 pins as shown in Fig. 2.

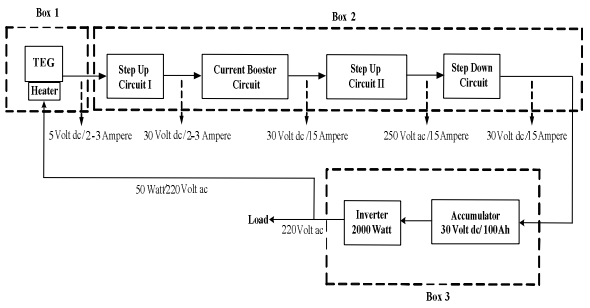

Fig. 1. Block Diagram of the TEG Application for Electrical Generation.

978-1-7281-2669-2/19/$31.00 ©2019 IEEE

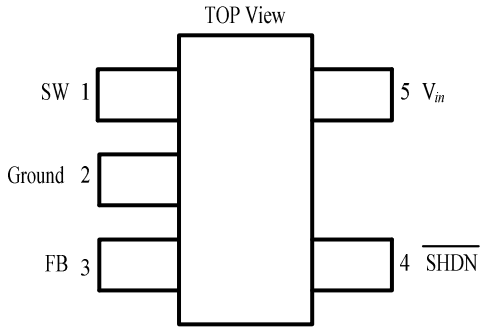

Fig. 2. IC LT 1615 as seen from the top [3].

Pin 1 functions as a SW (Switch), pin 2 functions as ground (GND), pin 3 functions as feedback (FB), pin 4 functions as $\overline{SHDN}$ (Comperator System). The device will be OFF if the voltage on pin 4 is 0.25 Volt and the device will reactivate if the voltage on pin 4 is 0.9 Volt, pin 5 is used for the power supply input source. This process takes place continuously and repeatedly until the output voltage is charged (until the FB / pin 3 pin reaches 1.23 Volts). Complete picture of IC LT 1615 is presented as a block diagram as shown in Fig. 3. In designing this step up using IC LT 1615, the desired objective is the input of 5 Volts and the output voltage (V_{out}) of 30 Volts, to achieve that a calculation of the L_1 inductor suitable for the system is needed. To calculate the magnitude of the L1 inductor that is suitable for this step up circuit, the equation given by the IC LT 1615 data sheet with the following formula can be used [6-8]

$$L = 2 \times (V_{out} + V_D / I_{lim}) \times t_{OFF} \qquad (1)$$

The data sheet of IC LT 1615 reveals that V_D is the schotty diode voltage of 0.4 Volt, I_{lim} is the setting of maximum current limit for the trigger system of 350 milliampers, and t_{OFF} is the off system time of 400 ns (OFF system time) [4].

Q_1, Q_2, R_3 and R_4 in Fig. 3 are coupling circuits to regulate the output voltage in the step up circuit [9]. When the voltage at pin 3 (feed back) is above 1.23 Volts, the comparator (Comperator A_1) deactivates most of the internal circuit IC LT 1615 and changes it from the internal circuit and the cycle is repeated. The output current is stored on the capacitor C_2 and will release it slowly until the voltage on pin 3 (FB) drops below the hysteresis point which is lower than the Comperator A_1 (hysteresis on pin 3 or FB is 8 milli Volt). The Comperator A_1 will turn on the power switch Q_3 and the current in the L_1 inductor starts to increase. Once the current reaches 350 mA, the Comperator A_2 will reset one shot, Q_3 up to 400 ns. The L_1 inductor then sends the current to the output via diode one (D_1). If the current at diode D_1 drops below 350 mA then Q_3 will turn on again and the current will rise again up to 350 mA, then the Comperator A_2 resets one-shot again causing L_1 to send the current to output again.

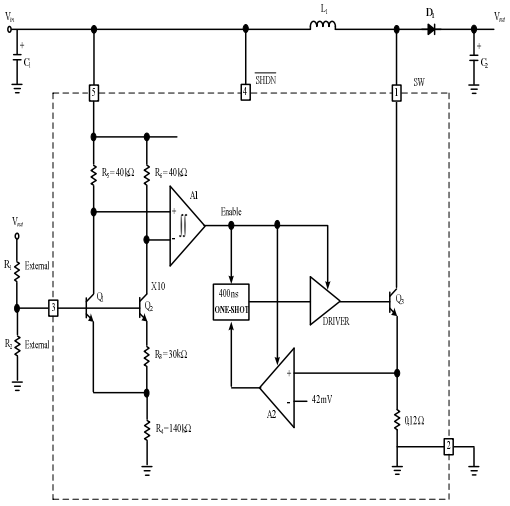

Fig. 3. Block diagram of IC LT 1615 [9-11].

B. Application of the Circuit of Step Up DC To DC Converter on the Power Plant

The output voltage of the thermoelectric generator (TEG) in box 1 is 5 Volt dc. This voltage will be increased by the Circuit of Step Up DC To DC Converter by 30 Volts dc which is in box 2 that can be seen in Block diagram of the TEG application for Power Plants (Fig. 1).

III. RESULTS AND ANALYSIS

A. Tool Design

In this design the materials used are: two resistors namely 2 MΩ and 130 kΩ, two capacitors namely 4.7 F / 50 Volt and 22 µF / 50 Volt, one inductor namelu 6948 µH, one diode of stocky type MER 0530, and one IC LT 1615. Whereas the tools used are: one solder, one clamp meter, one multimeter, two screwdrivers each of which is a plus and a minus one, one solder tin roller, one electric saw, and one electric drill.

The design results are in box 2 of the block diagram of Fig. 1 as shown by the white block in Fig. 4.

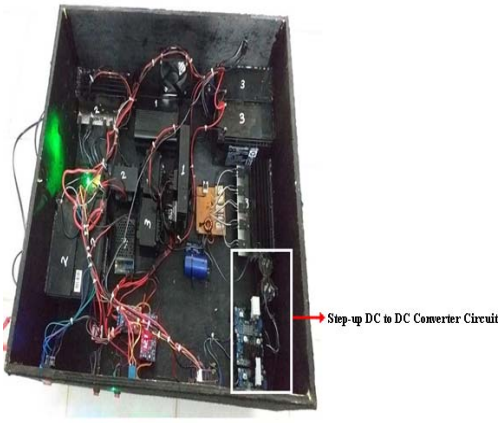

Fig. 4. Results of the Design of the Circuit of Step Up DC To DC

Converter in box 2 on the block diagram of Fig. 1.

B. Results of Measurement

The results of the measurements of the overall tool design in the physical form of Fig. 4 can be seen as shown in Fig. 5 which are loaded with LED lights whose magnitude varies from 60, 75, 90, 130, 180, 300 and 500 Watts as shown in Fig. 6. The results of the measurement in the form of the incoming and outgoing voltage in the Circuit of Step Up DC to DC Converter are shown on Table 1.

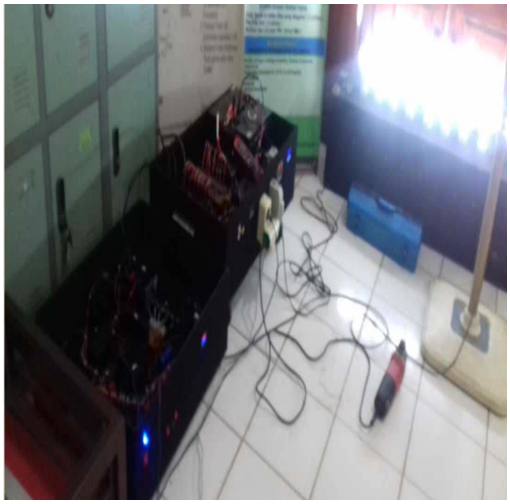

Fig. 5. Physical Form of Fig. 1.

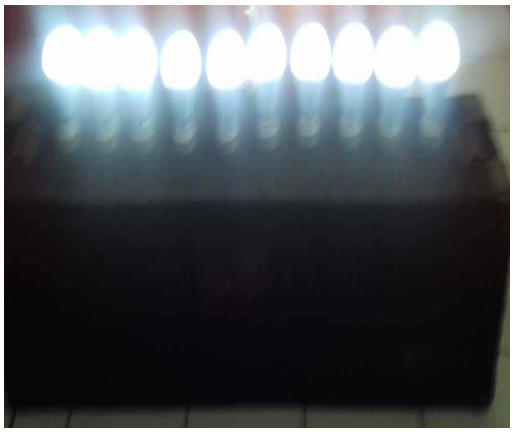

Fig. 6. The Load of the Circuit of TEG application for Generators.

Table 1. The results of measurement of incoming and outgoing voltage of the circuit of the Step Up DC To DC Converter with varying loads.

Loads (Watt)	Incoming Voltage (Volt)	Outgoing Voltage (Volt)	Description
60	5.43	29.57	Loaded with LED lights of Hannochs brand
75	5.25	29.18	
90	5.08	29.07	
130	4.95	28.85	
180	4.78	28.56	
300	4.13	27.03	
500	4.07	25.47	

C. Analysis

This circuit of step-up converter is created to increase the voltage from 1-6 Volts to a maximum voltage of 30 Volts dc. The increase in voltage reaching the maximum of 30 Volts dc is obtained from IC LT 1615 which is a micro power Step Up DC To DC Converter in which the input voltage starts from 1 Volt to 6 Volts and the output voltage ranges from 7 Volts to a maximum of 35 Volts.

The results of the measurement shown in Table 1 can be presented in graphical form as in Fig. 7.

The data in Fig. 7 reveal that the magnitude of the outgoing voltage in the circuit averages 6 times of the input voltage. The difference between the incoming and outgoing voltage is quite large when loaded with 60 Watts, the incoming voltage of 5.43 Volts and the outgoing voltage of 29.57 Volts. There is a significant decrease between the incoming and outgoing voltage when it starts to load 300 Watts, the incoming voltage is 4.13 Volts and the outgoing voltage of 27.03 Volts. To prevent the circuit from being damaged due to excessive heat, the system should be loaded under 500 Watts.

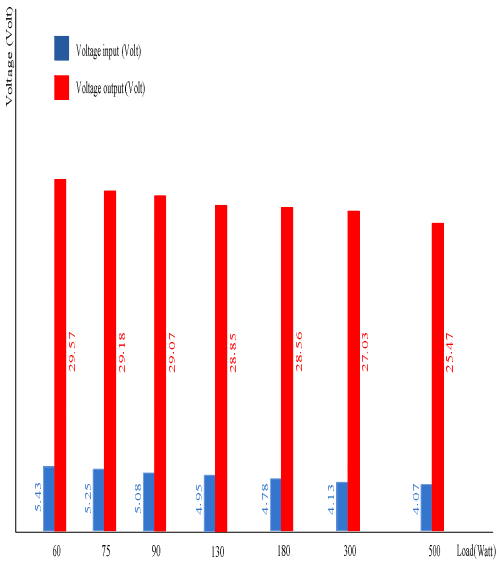

Fig. 7. The graph of measurement results of loads against incoming and outgoing voltages.

The desired results of designing the Cuircuit of the Step Up DC To DC Converter using IC LT 1615 is the input voltage (V_{in}) of ± 5 Volts and the output voltage (V_{out}) of ± 30 Volts. Another important thing is the calculation of the L_1 inductor that is suitable for the system. The inductor L_1 can be calculated using Equation (1) in which the IC LT 1615 data sheet reveal that V_{out} = 30 Volts, V_D = 0.4 Volt, I_{lim} = 350 milliamperes, and t_{OFF} = 400 ns. So

$$L = 2 \times \{(30 + 0.4)/(350 \times 10^{-3})\} \times 400 \times 10^{9} \approx 70\ \mu H$$

IV. Conclusion

The circuit of Step-Up DC to DC Converter IC LT 1615 is a circuit to increase 5 Volt voltage (as an input voltage) to 30 Volts (as output voltage). If the input voltage is less than 1.23 Volts the circuit cannot work properly. The input and

output currents in this circuit are between 2-3 amperes with a maximum system load of 500 Watts.

REFERENCES

[1] Hea W, Zhang G, Zhang X, Ji J, Li G, Zhao X, "Recent development and application of thermoelectric generator and cooler," Appl Energy, vol. 143, 2015, pp. 1-25.

[2] S. Radhakrishnan, Venugopal LV, Vanitha M. Hardware, "Implimentation of Linear Current Booster for Solar Pumping Applications," ARPN Journal of Engineering and Applied Sciences, vol. 11(1), 2016, pp. 1124-1126.

[3] Peter K. Wu, Justin C. Biffinger, Lisa A. Fitzgerald, Bradley R. Ringeisen, "A low power DC/DC booster circuit designed for microbial fuel cells," Process Biochemistry, vol. 47, 2012, pp. 1620-1626.

[4] P. Hogenboom, "Data sheet book 3," Uitgeversmaatschappij Elektuur B.V, 1988.

[5] A.M Ball, "Semiconductor data book," Newnes Technical Books, 8th Edition, 1984.

[6] Gayawakad RA, "Op-Amps and Linear Integrated Circuits," Prentice-Hall, 3rd Edition, 1993.

[7] Aelterman P, Rabaey K, Pham HT, Boon N, Verstraete W, "Continuous electricity generation at high voltages and currents using stacked microbial fuel cells," Environmental Science & Technology, 2006, pp. 3388-3394.

[8] Clayton G, Winder S, "Oprational Amplifiers," Arrangement Elsevier Limited, 5th Edition, 2003.

[9] I.M. Gottlieb, "Power Suplies, Switching Regulators, Inverters & Convertrs," McGraw-Hill, 1993.

[10] Mohan N, Undeland TM, Robbins WP, "Power electronics: converters aplplications and design," John Wiley & Sons. Inc, 2003.

[11] M.H. Rashid, "Power Electronics, Devices, and Applications," 3rd Edition, Pearson Education, 2004.