A Study on Renewable Energy Harvesting and Circuit Design Based on a Maximum Power Point

HoSeong Cho, YongYun Cho, ChangSun Shin and JangWoo Park[1]
Dept. Of Information & Communication Engineering, Sunchon National University
413 Jungangno, Suncheon, Jeonnam 540-742, Korea
{thsgk1215, yycho, csshin, jwpark }@sunchon.ac.kr

Abstract

In the recent studies of the renewable energy harvesting, it has been one of the most important research topics how to efficiently find a maximum power point. A maximum power point means that its power becomes the maximum by a relational expression between voltage and current. This paper suggests a new method on how to efficiently find a maximum power point for obtaining renewable energy, and testifies the validity of the method through an optimized circuit design for harvesting renewable energy.

Keywords: *Maximum Power Point; Renewable energy; Energy Harvesting*

1. Introduction

Generally, most sensor nodes in real environments have been used in a modularized type due to their power problems, and they also have a simple structure which consists of only a few sensors and RF communication modules. They have a lower setup cost and a simpler structure than other wireless networks, so that they have been applied into the various fields such as defense, manufacturing, construction, logistics, distribution, transportation, education, medicine, environment, agriculture/livestock industries and so on [1, 2].

In the USN, a sensor node's hardware is generally designed to be used on low power, so that it could be used by means of two AA batteries with 1,500mA for more than about one year. However, if a sensor node tries to check and process many of data according to the sensor environments, its power consumption would be increased proportionately and battery power would be decreased more quickly. These facts become the cause that a user may have trouble getting sensing data from sensor nodes and having confidence in the reliability of the sensing data when the battery life comes to about an end. To resolve these problems related with a battery life of a sensor node, many studies about driving sensor nodes with renewable energy have been actively conducted [3, 4, 5, 6]. In obtaining renewable energy, finding a maximum power point is the most important factor to determine the performance of a system. In this paper, we propose a new method to effectively find a maximum power point through a design of photovoltaic circuits and its simulation.

The rest of this paper is organized as follows. In Section 2, we introduce a new method to find a maximum power point. Section 3 designs a circuit for harvesting renewable energy in sensor nodes using the suggested method. And, Section 4 describes results of simulation for the circuit designed. Finally, Section 5 concludes this paper.

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[1]Corresponding author : JangWoo Park

2. Maximum Power Point Tracking

In respect of energy respect, renewable energy has an advantage that it does not require any electrically additional power source, because it can use the surrounding environment as an energy source. However, it has also a disadvantage that its input is not constant. In other words, power of its input resource is changed from moment to moment, and there may be no input in some cases.

For example, a power degree of renewable energy from sunlight can have varied according to the passing of time and the changing of seasons. In a system using renewable energy, the MPP is an indispensable element for increasing the gaining rate of renewable energy.

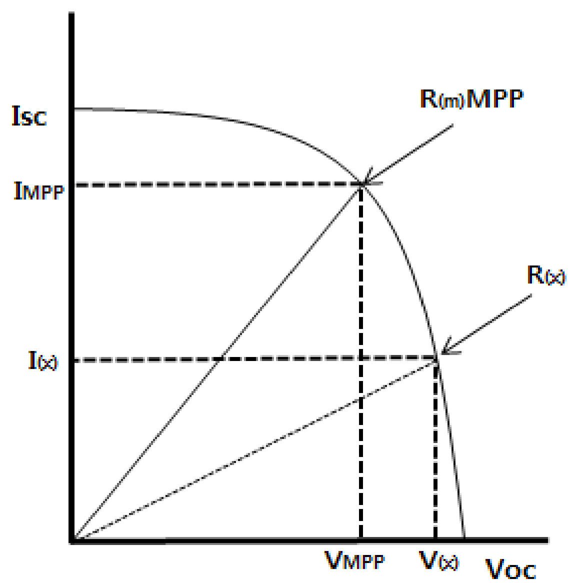

Figure 1. A MPP Graph of *Voc* and *Isc*

Figure 1 represents the Maximum Power Point (MPP) of *Voc* and *Isc*. The MPP can be found by calculating V_{MPP}. Eq. (1) shows an expression to find V_{MPP}. V_{MPP} means a maximum power point voltage. And, k means constant fraction, V_{OC} is open-circuit voltage. And, c is an offset of a linear fit. V_{MPP} is proportional to *Voc*, and k is an important parameter to determine a level for finding V_{MPP} [7].

$$V_{MPP} = k\ V_{OC} + c \qquad (1)$$

Figure 2 shows that MPP varies with the input powers, and shifts on the line of fixed V_{MPP}.

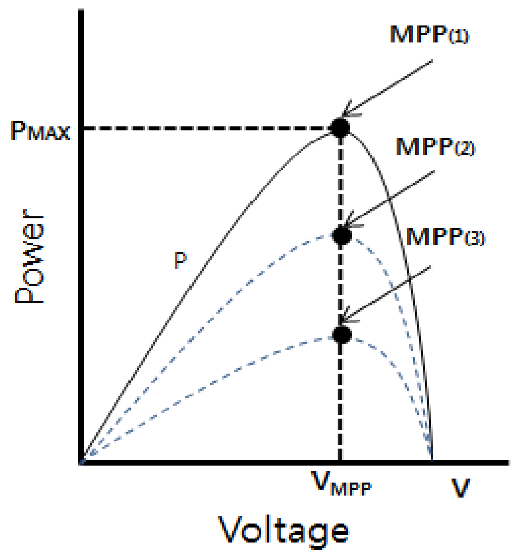

Figure 2. A MPP's Change Pursuant to the Power

3. A Circuit Design for Finding a Maximum Power Point of Renewable Energy

3.1. Input Voltage Level Circuit

Figure 3 is the circuit to determine a level of input voltages. Resistors R1, R2 and R3 divide voltages to determine the *k* value, and the voltage is applied to the IN-pin of LTC1440, comparator, in order to determine V_{MPP}.

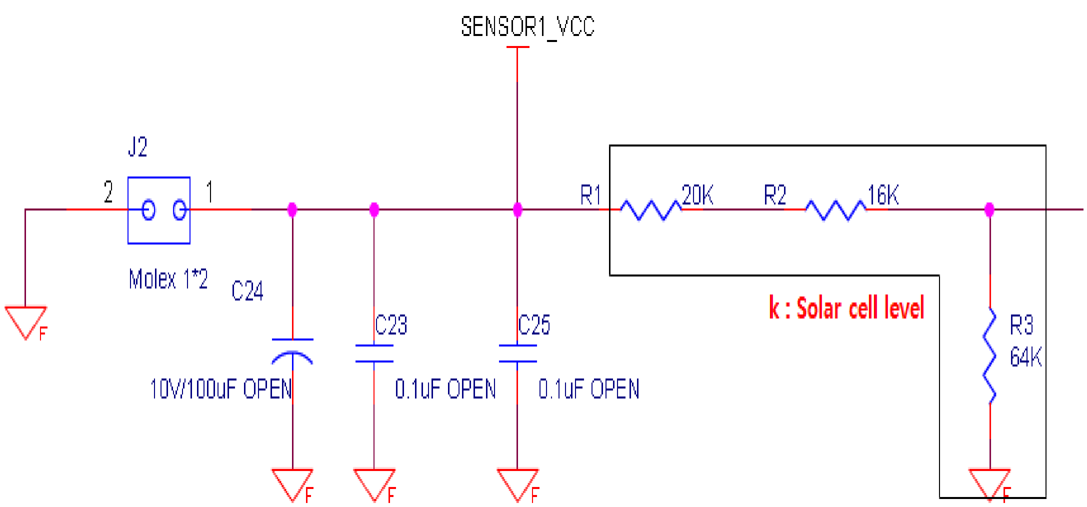

Figure 3. An Input Voltage Level

3.2. Comparator and DC/DC Converter

LTC1440 is a comparator that can use hysteresis. Hysteresis can be used by connecting a resistor between the REF pin and the HYST pin, and connecting a second resistor between the HYST pin and the V- pin as shown in Figure 4. If hysteresis is not used, it makes sure the HYST pin is connected to the REF pin [8].

LTC1440 in Figure 4 compares signals entered into the IN+ and IN- pins to output it to the OUTPUT. Voltages entered via the solar panel gets into the IN+ pin, and the MPP is tracked by switching according to the *k* of the IN-pin entered from the photosensor. A maximum power point can be tracked with the DC/DC convertor. The box part in Fig. 4 represents a DC/DC boost convertor, in which the SHDN pin of LTC3401 plays a role of a switch. The switch is controlled by a PWM signal, so that it can track a maximum power point.

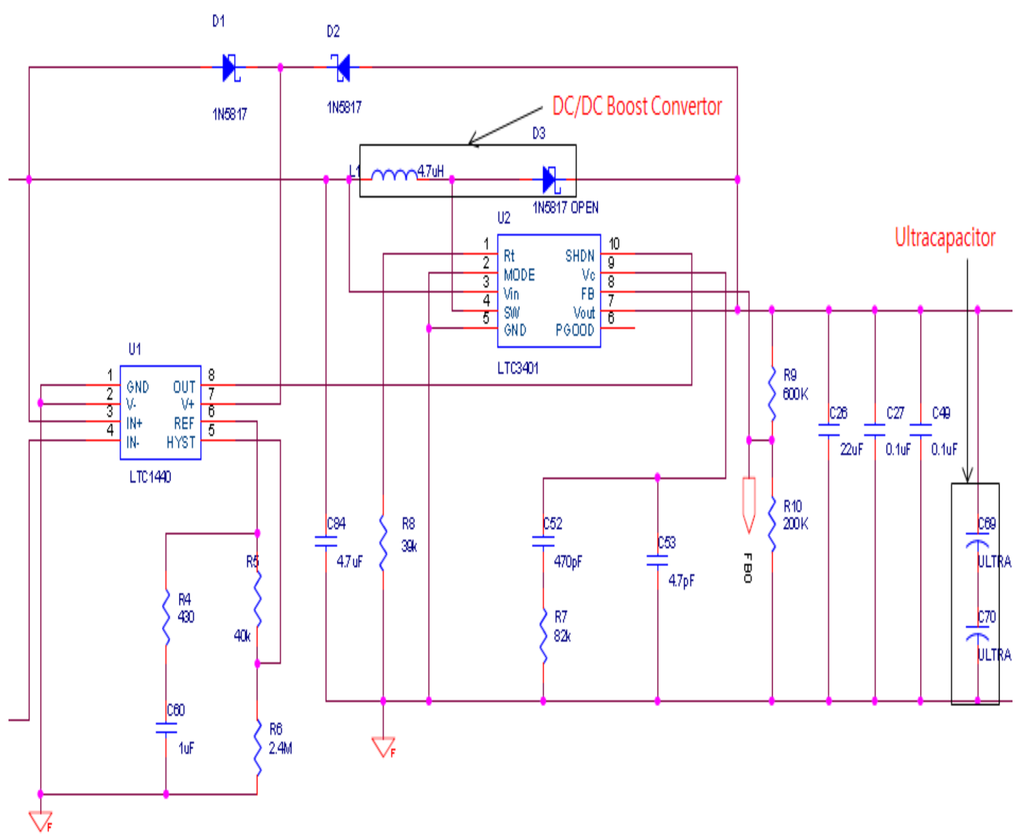

Figure 4. A Comparator and a DC/DC Convertor

LTC3401 is a boost convertor, of which efficiency of synchronous rectification is 97%, and it is used as a synchronous boost convertor that can convert a current rate up to 1A. This convertor can simultaneously drive an external timing resistor and an external clock [9]. The schottky diode, 1N5817, is selective, however, it is attached to increase power efficiency.

4. Results of the Simulation

4.1. Important Parameter *k* for Finding V_{MPP}

This chapter carries out a simulation for the charging time and output voltage of the ultra-capacitor depending on the *k* value in Eq. (1) to determine an input voltage level explained in Section 3. Because the *k* is a very important parameter for finding V_{MPP}, it is simulated for different *k* values by changing the R2 value in Figure 5. LTspice was used for this simulation.

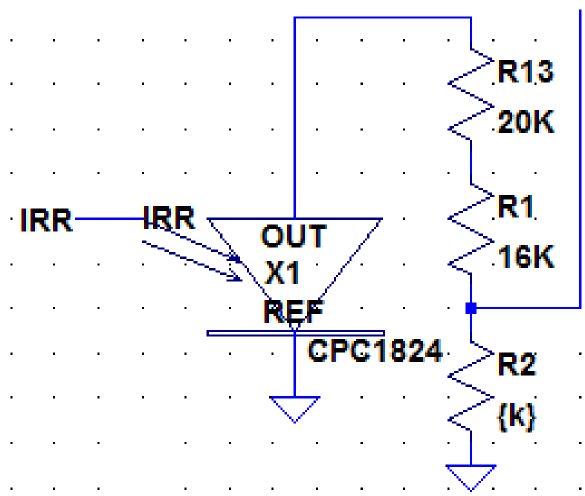

Figure 5. A Simulation Circuit for the Input Voltage Level *k*

The simulation is carried out by changing the R2 value in Figure 5 with 32k, 64k, 256k and 512k. Consequently, the result can be obtained as Figure 6. Figure 6 shows the output voltage depending on the *k* in a bar graph. And Figure 7 shows the actual graph of the simulation.

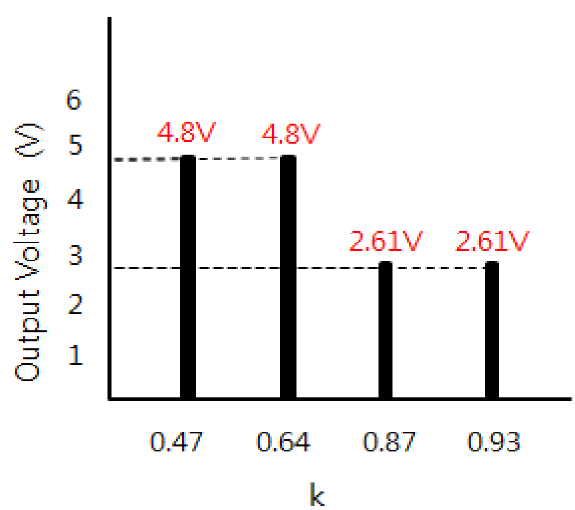

Figure 6. A Bar Graph of Output Voltage Depending on the *k*

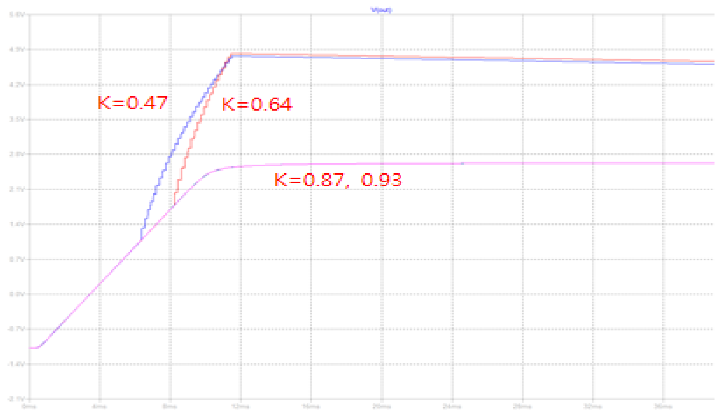

Figure 7. A Simulation Result of Output Voltage Depending on the *k*

Figure 8 is the output graph of the LTC1440 circuit, and Fig. 9 is the input voltage from the solar panel and the photosensor.

Figure 8. A Output of the LTC1440 Circuit

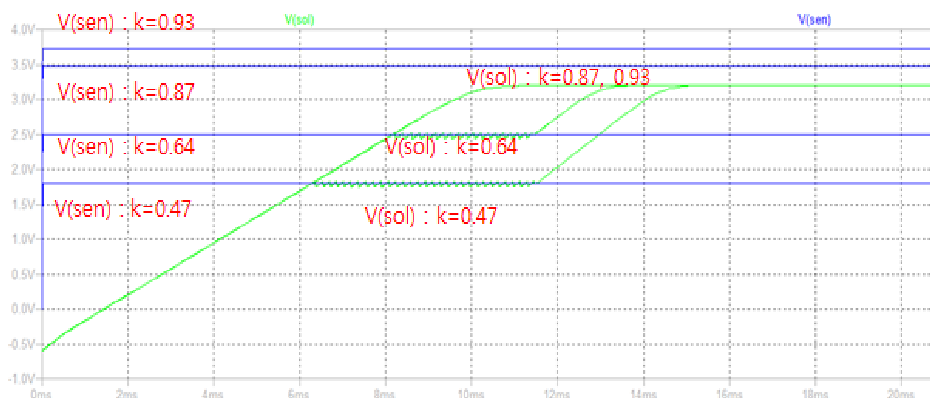

Figure 9. An Input Voltage of a Solar Panel and a Photosensor

Output of the LTC1440 circuit is a circuit to track the MPP, but the tracking is not taken place when the *k* is 0.87 and 0.93. The reason is that the input V(sol) of the solar panel does not meet the input V(sen) of the photosensor that determines the level.

4.2. A Simulation for Input Energy Intensity

Figure 10 shows an ultra-capacitor's charging time depending on an input energy intensity. The stronger the input energy intensity is, the shorter the charge time.

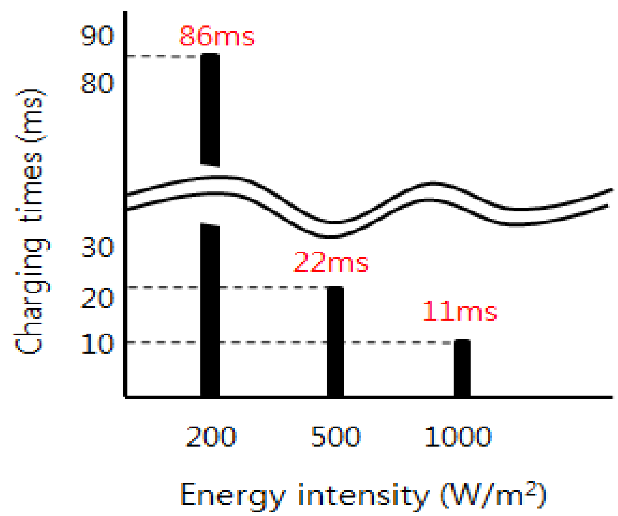

Figure 10. An Input Energy Intensity According to the Ultra-capacitor Charging Time

Figure 11 shows an output voltage depending on energy intensity. The output voltage represents a constant output regardless of the input energy intensity. The reason is because the output comes out after charging the ultra-capacitor.

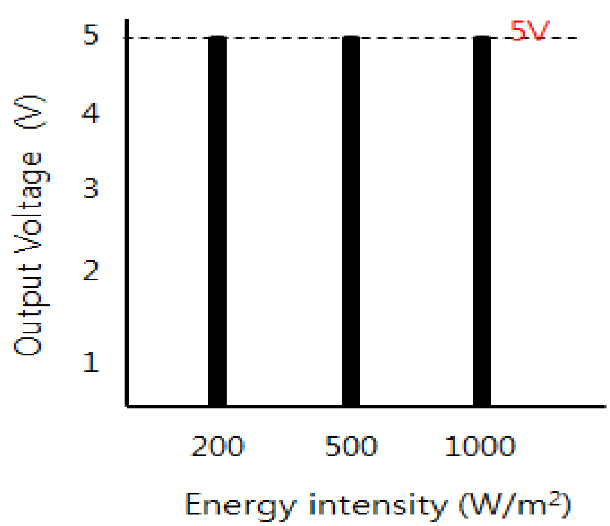

Figure 11. The Input Energy Intensity According to the Output Voltage

Figure 12 shows an actual graph of the simulation. Depending on energy intensity, we can see the difference of the charging time.

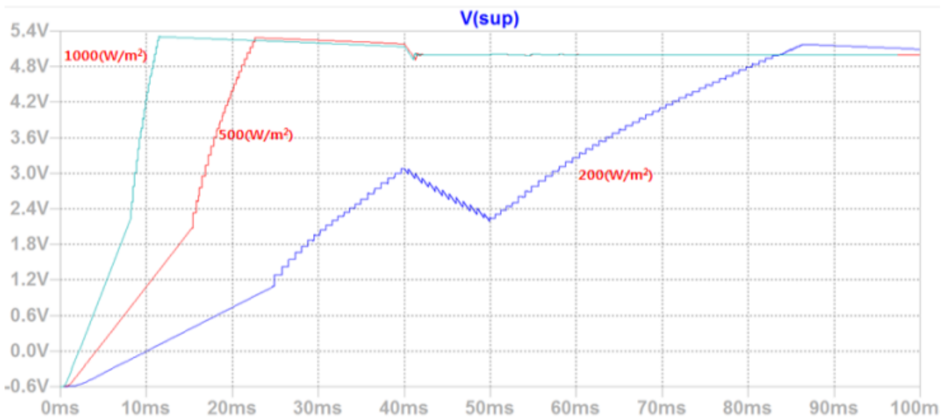

Figure 12. A Simulation of Input Energy Intensity According to the Output Voltage

4.3. Simulation for Input and Output of the Whole Circuit

Figure 13 shows the whole circuit diagram. In the Section 4.1 and 4.2, the simulation was carried out without a battery circuit. In this section, a simulation is carried out with a battery circuit for an input/output.

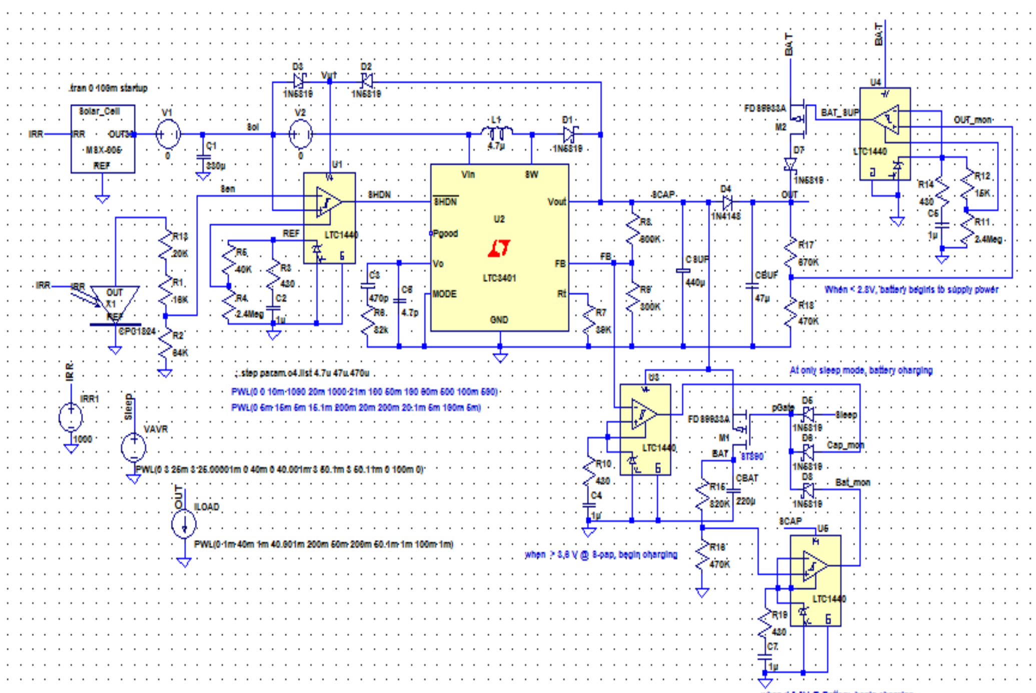

Figure 13. A Simulation Circuit

Table 1 represents a simulation environment for a whole circuit. In order to reduce the simulation time, we increased the quantity of light, and designed the circuit with low-capacity ultra-capacitors and batteries. The output voltage is designed as 3.9 V that can drive usual sensor nodes.

Table 1. A Basic Environment for Simulation

Input Voltage	3.3 [V]
Input Voltage Level	2.75 [V]
Output Voltage	3.9 [V]
Ultra Capacitor's Capacity	440 [μF]
Battery Capacity	220 [μF]

Figure 14 is a graph that plots the input voltage and the input voltage level in the simulation for the whole circuit. The V(sen) is the level of input voltage, and the V(sol) is the voltage of solar panel. The charging time of ultra-capacitors is from 0ms to 5ms. The voltage of the solar panel is entered depending on the voltage level while the ultra-capacitor is charged, and the original 3.3 V comes out after charging the ultra-capacitor. The time to charge the battery is from then to 25ms ~ 27ms. At this time, the output voltage from the solar panel follows the voltage level again, and it shows 3.3V again when charging of the battery is completed.

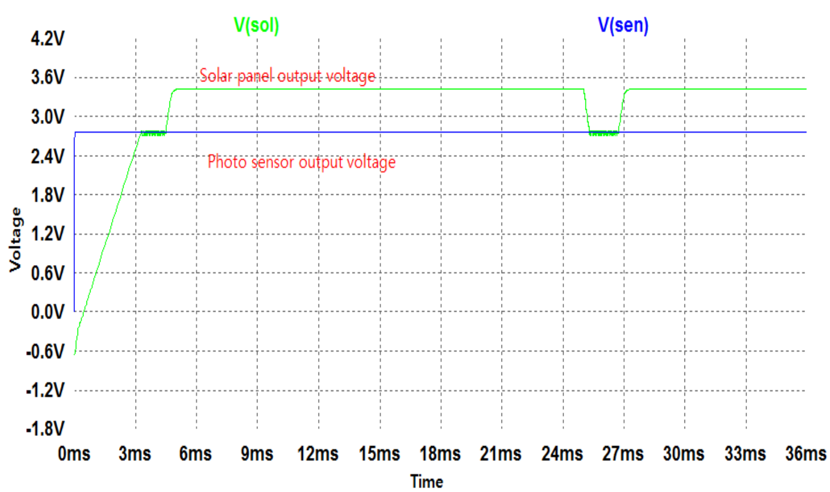

Figure 14. An Input Voltage and an Input Voltage Level of the Circuit

Figure 15 represents a voltage and a current at the ultra-capacitor stage. The current is generated when the ultra-capacitor is charged, and the ultra-capacitor stage shows a ripple voltage due to the effect of charging/discharging. And we can observe that the currents are also varied significantly.

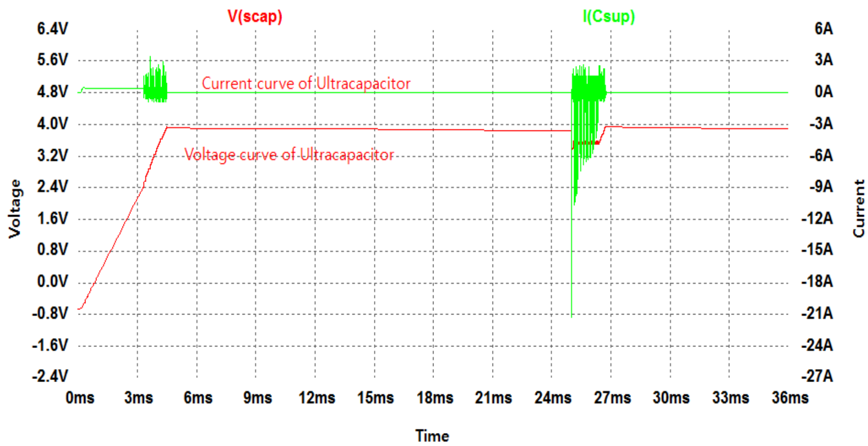

Figure 15. A Voltage and a Current at the Ultra-capacitor Stage of the Circuit

Figure 16 is a graph representing voltage and current at the battery stage. It means that the voltage of battery was increased and it was charged whenever the current rises.

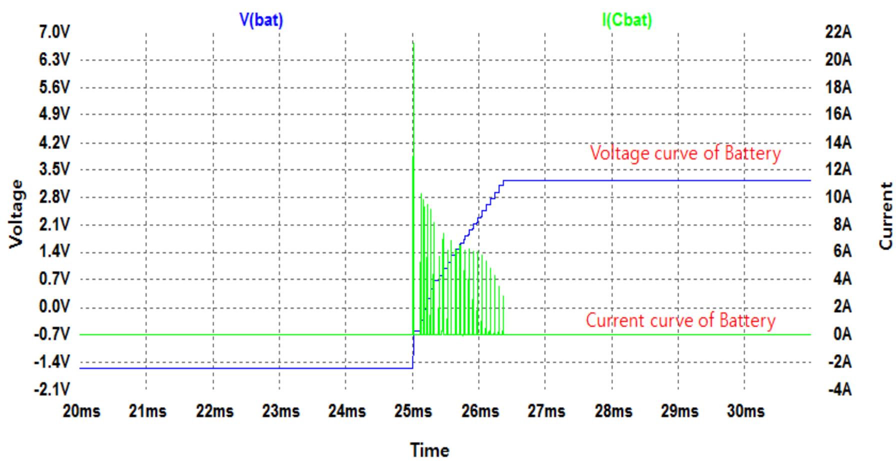

Figure 16. A Voltage and a Current at the Battery Stage of Circuit

5. Conclusions

In this paper, we propose a new method to find a maximum power point of sensor nodes using renewable energy in order to extend the sensor node's life. A maximum power point refers to a point, at which a sensor node’s power becomes a maximum through the proper ratio between a voltage and a current. And, we designed a circuit with a DC/DC convertor to obtain renewable energy. The designed circuit uses a DC/DC convertor for tracking a maximum power point and a switch controlled by the PWM signal. In addition, the MPP can be found through the V_{MPP}. Through the simulations, we showed the possibility that the suggested method can be useful in the real environment by showing the meaningful output of the ultra-capacitor for different k, which is an important parameter for finding the V_{MPP}.

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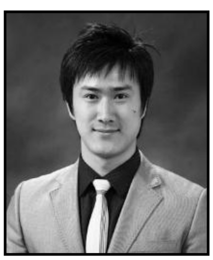
References

[1] W. Lei, W. Tongsen and Y. Ronghua, International Journal of Advanced Science and Technology (IJAST), vol. 2, **(2009)**.
[2] A. Ko and H. Y. K. Lau, International Journal of Advanced Science and Technology (IJAST), vol. 3, **(2009)**.
[3] C. Park and P. H. Chou, Sensor and Ad Hoc Communications and Networks, **(2006)**.
[4] D. J. de Villiers, Cape Peninsula University of Technology, **(2009)**.
[5] S. Laurier, Electronics and Information systems, University of Ghent, Belgium, **(2007)**.
[6] R. Sheikhpour, S. Jabbehdari and A. Khadem-Zadeh, International Journal of Advanced Science and Technology (IJAST), vol. 36, **(2011)**.
[7] L. Castaner and S. Silvestre, Modelling Photovoltaic Systems using PSpice, John Wiley & Sons Ltd., **(2002)**.
[8] E. Koutroulis, K. Kalaitzakis and N. C. Voulgaris, IEEE TRANSACTIONS ON POWER RLRCTRONICS, vol. 16, **(2001)**.
[9] Y. C. Kuo, T. J. Liang and J. F. Chen, IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS, vol. 48, **(2001)**.

Authors



HoSeoung Cho

Received his BS and MS degrees in Information and Communication Engineering from Sunchon National University, Suncheon, Korea, in 2010 and 2012, respectively. Currently, he is an assistant manager of Power Engineering Co., Ltd. His research focuses on new renewable energy and RFID/USN technologies.

YongYun Cho

Received his BE in Computer Science from Inchoen University, Korea, in 1995, and received MS and PhD in Computer Engineering from Soongsil University, Korea, in 1998 and 2006, respectively. Currently, he is a Professor at Information and Communication Engineering, Sunchon University. His research interests include context-aware workflow, smart robot and semantic web.

ChangSun Shin

Received the PhD degree in computer engineering at Wonkwang University. Currently, he is an assistant professor of the Department of computer & communication engineering in Sunchon National University. His main research interests include Distributed Real-Time Computing, Distributed Object Modeling, Ubiquitous agriculture and Ubiquitous Sensor Network (USN).

JangWoo Park

Received the BS, MS and PhD degrees in Electronic engineering from Hanyang University, Seoul, Korea in 1987, 1989, and 1993, respectively. In 1995, he joined the faculty member of the Sunchon National University, where he is currently a professor in the Department of Computer & Communication engineering. His research focuses on RFID circuits and system designs and RFID/USN technologies.