Faculty of Electronic and Computer Engineering

LOW VOLTAGE AMPLIFICATION USING SELF STARTING VOLTAGE REGULATOR FOR STORAGE SYSTEM

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A thesis submitted
in fulfillment of the requirements for the degree of Master of Science
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DECLARATION

I declare that this thesis entitled “Low Voltage Amplification Using Self Starting Voltage Regulator for Storage System” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : .....

Name : .....

Date : .....

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Master of Science in Electronic Engineering.

Signature :…….....

Supervisor Name :…….....

Date :…….....

DEDICATION

To my beloved mother and father,

My husband and children,

whose steadfast love and

inspires my work.

ABSTRACT

This thesis presents a storage system design based on energy harvesting to achieve battery-less use for low power application. This thesis basically deals with the effectiveness of DC to DC converter to boost the low input voltage of the harvested energy for energy storage system. This storage system's function is to store the harvested energy collected from the environment surroundings such as vibration, salinity, RF energy and many more. As generally known, the output voltage of the harvested energy is insufficient for most applications and only generates extremely low power. In the case of wireless sensor network, for example, the sensor node would require energy only during transmitting and receiving data whereas during standby mode or sleep mode, the amount of energy required would be very small. Therefore, the storage system will make use of this standby time or sleep mode of the sensor node to store as much energy as possible. Moreover, a converter must be designed to boost up low input voltage harvested through vibration energy to the higher dc voltage. The method discussed in this thesis gives a promising solution to boost the low input voltage which comes from the rectified voltage of energy harvesting sources that is known to be extremely low voltage. The proposed approach is using MOSFET with the capability of fast switching to perform as the main switch and also as a switching regulator. The MOSFET will be driven by the Pulse Width Modulation (PWM) generated by oscillating circuit which is able to work even at low input voltage by using JFET component. The designed boost converter must be capable and sufficient to charge the super capacitor as an energy storage device and also provides power to energize the load application. The simulation and experimental results showed that the circuit is able to boost the input voltage as low as 0.1 V up to 0.75 V with the range of power efficiency within 82 % to 90 %. Even though the output results from the hardware experiment was lower than the simulation results where the efficiency of simulation can achieved up to 90 % but the experimental result only can achieved maximum 87 %, this is expected as there will be power losses at the component circuit especially in oscillation path, series resistance, diode and also the MOSFET.

ABSTRAK

Tesis ini membentangkan reka bentuk sistem penyimpanan berdasarkan penuaian tenaga untuk mencapai penggunaan tanpa bateri untuk aplikasi berkuasa rendah. Tesis ini adalah pada dasarnya berkaitan dengan keberkesanan penukar arus terus (AT) ke arus terus(AT) untuk meningkatkan input voltan yang rendah dari tenaga yang dituai untuk sistem penyimpanan tenaga yang berfungsi untuk menyimpan tenaga yang dituai daripada persekitaran alam sekitar seperti getaran, kemasinan, tenaga frequensi radio dan banyak lagi. Seperti yang diketahui bahawa voltan keluaran tenaga yang dituai adalah tidak mencukupi bagi kebanyakan aplikasi dan hanya menjana kuasa yang amat rendah. Dalam kes rangkaian sensor tanpa wayar sebagai contoh, setiap nod memerlukan tenaga untuk menghantar dan menerima data manakala dalam mod siap sedia atau mod tidur, jumlah tenaga yang diperlukan akan menjadi sangat kecil. Oleh itu sistem penyimpanan pada masa ini akan menyimpan tenaga sebanyak mungkin. Selain itu litar penukar dari arus terus ke arus terus perlu direka untuk meningkatkan input yang dituai daripada tenaga getaran rendah kepada voltan yang lebih tinggi. Kaedah yang dibincangkan dalam tesis ini memberikan penyelesaian bagi meningkatkan voltan input yang rendah dari sumber penuaian tenaga. Pendekatan yang disyorkan adalah dengan menggunakan MOSFET dengan kemampuan pensuisan pantas sebagai suis utama dan juga sebagai voltan pengatur pensuisan. MOSFET ini akan dipacu oleh Modulasi Lebar Denyut (PWM) yang telah dihasilkan oleh litar yang mampu berfungsi pada voltan input yang rendah dengan menggunakan komponen JFET. Litar penukar arus terus ke arus terus yg di reka mesti mencukupi untuk penyimpanan tenaga di dalam super kapasitor yang akan menyediakan kuasa untuk memberi tenaga kepada beban. Simulasi dan keputusan eksperimen menunjukkan bahawa litar dapat meningkatkan sehingga voltan yang serendah 0.1V sehingga 0.75V dengan julat kuasa kecekapan dari 82% sehingga 90 %. Walaupun hasil keluaran dari eksperimen prototaip adalah lebih rendah daripada keputusan simulasi iaitu untuk simulasi kuasa kecekapan boleh mencapai 90 % manakala bagi prototaip hanya boleh mencapai maksimum 87 %, tetapi ini telah dijangka kerana dalam simulasi, segala komponen elektronik adala ideal iaitu tidak akan kehilangan kuasa di litar komponen terutama dalam laluan ayunan, rintangan siri, diod dan juga MOSFET.

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AC	-	Alternating Current
CCM	-	Continuous conduction mode
DC	-	Direct Current
DCM	-	Discontinuous conduction mode
RF	-	Radio Frequency
PWM	-	Pulse Width Modulation
WSN	-	Wireless Sensor Network
B	-	Strength of the magnetic field
C	-	Capacitance value
d	-	Piezoelectric strain coefficient
D	-	Charge density
D	-	Duty cycle
E	-	Electric field
ε	-	Dielectric constant
i	-	Current
L	-	Inductor
ℓ	-	Length of the spring coil
N	-	Number of turns in the spring coil
η	-	Power efficiency
P	-	Power

Q	-	Charge on the capacitor
V	-	The voltage between the capacitor plates
ω	-	Excitation angular frequency
y	-	The movement of the coil through the magnetic field
δ	-	Mechanical strain
σ	-	Mechanical stress
λ	-	Ratio of inductance value
Z	-	Impedence

LIST OF PUBLICATIONS

1. Mohd Nasir, Haslinah and Mohamed Aminuddin, Mai Mariam, 2014. Efficient Low Voltage Amplification using Self Starting Voltage Regulator for Storage System. *International Journal of Engineering and Technology (IJET),* vol.6, no.5 pp.2465-2471.
2. Mohd Nasir, Haslinah and Mohamed Aminuddin, Mai Mariam, 2014. The Design of Self Starting Regulator Using Step-Up Converter Topology for WSN Application. *WSEAS Transactions on Circuits and Systems*, vol.13, pp.291-295.

CHAPTER 1

INTRODUCTION

1.0 Introduction

This chapter will elaborate the background and the motivation of the research work. The purpose and the scope of work will also be briefly discussed. At the end of this chapter, the organisation of this research work will be explained.

1.1 Research Background

Continuous monitoring is very important for chronic patient, elderly or anybody who requires supervision for recovery from an acute event or surgery. For this, Wireless Sensor Network (WSN) gives a solution for continuous health monitoring and is able to wirelessly monitor patient's conditions at any given time. It will generate early warning in case of an alert signal received from the patient. Despite this, this WSN only consumes very little power to turn on and therefore energy harvesting is able to power up this device without the need of batteries. Continuous monitoring needs a continuous and uninterruptable power source. Hence, energy harvesting is one of the options that are available for the solutions. Therefore, this research work proposed a new technique called a self-starting DC to DC converter, which is able to boost the input voltage from low amount of power that is delivered from the energy harvesting devices. In regards to harvesting circuitry, this research work also develops a storage system using super capacitor that can be used to power up higher power application at the interval period. This chapter presents the motivation for carrying out this research, the contribution of the

research and scope of the work. The chapter ends with a description of the research organisation.

1.2 Problem Statement

In many applications nowadays, battery-less or self-powered operation is the best option to choose as we are heading towards the 'green world'. The use of batteries causes a huge negative impact on the environment because they are not appropriately recycled. Furthermore, it needs to be replaced and disposed eventually as stated by Frost & Sullivan (C.R. Malavika, 2004). In addition to the bulky size and high maintenance cost requirement, it is not practical in view of the fact that electronic devices are becoming more and more ubiquitous and pervasive (Mcleod, 2004). Therefore, energy harvesting can be an alternative to micro-powering the electronic devices and in order to achieve battery-less system, energy storage such as super capacitor is required. Energy harvesting is actually a process of extracting unusable energy from the surroundings and then converting it into a useable form of electric energy (Huang et al., 2010). The energy storage system is used for renewable energy application as well as improving the power quality in the transmission and distribution of power system.

In recent times, the topic of energy harvesting is becoming more popular and attracts global attention. Renewable energy sources are already known as environmental friendly energy supplies that are popular nowadays. Many types of energy sources are available and can easily be found in the surroundings such as vibration, temperature difference, Radio Frequency (RF), light, motion and many more. There are a lot of researches that have been conducted on this and the most challenging part is to increase the low voltage that is generated from energy harvesting transducers such as thermal generators, piezoelectric element, etc. Due to this, the output power from the harvested

energy is not in the useable form that is required to power up certain applications (Raju and Grazier, 2010). Hence, there is a need to develop a system that is able to convert the harvested energy into a useable electrical energy form, so that it will be able to power up low power applications such as microcontrollers and wireless sensor networks, which only need power in the range of micro to mille watts to operate.

Apart from that, the combination of energy conversion with suitable energy storage is also needed to make sure that the system is able to work continuously without relying on batteries. Relying on batteries for WSN is really impractical as the number of sensor nodes can reach up to thousands or even millions depending on the application. In most of the cases, sensor nodes are deployed in remote areas where the access is absolutely limited. Therefore, an alternative power source is needed to replace the traditional way of using batteries. The approach of energy harvesting in this case seems to give a promising solution.

1.3 Research Work Objectives

The objectives of this research work are:

a) To design a self-starting DC to DC converter that is able to boost the low input voltage from vibration as the energy source to a higher regulated DC output voltage
b) To design the energy storage system that is able to work effectively with the boost converter to achieve the battery-less system.
c) To analyse the efficiency of the combination of the DC to DC converter with the energy storage system.

1.4 Contribution

The main contributions of this research are:

i. Both simulation and hardware implementation of a DC to DC converter are completed with the range of power efficiency is from 81 % to 90 %. This proved that the DC to DC converter circuit design is better compared to the existing DC to DC converter with the same method used.

ii. The development of an energy storage system based on a super capacitor circuit in combination with a DC to DC converter. The selection of super capacitor as the energy storage system is due to its capability of storing energy that is associated with any renewable energy with low cost and maintenance.

iii. The comparison of using different components for AC to DC rectifier to reduce the voltage loss at the output is presented. Based on the results, it is shown that the full bridge rectifier based on the Schottky diode is much better than using either self-driven MOSFET or regular diode in terms of reducing the voltage loss at the output circuit.

iv. This research will benefit the energy sector to replace the use of batteries and also to the biomedical engineering field especially to power up the low power implantable sensor.

1.5 Scope of Research Work

The scope of this research work will cover two parts from the harvesting circuitry system, namely the step-up DC to DC converter and the energy storage system. This can be seen in Fig 1.1.

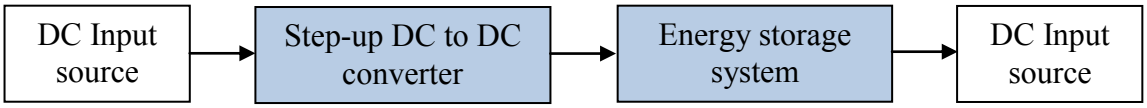

Figure 1.1 The research scope.

This research is limited to focus on the design of the DC to DC converter, which has the ability to boost the low input voltage within range of 0.1 V upto 0.75 V to the higher output voltage and then be stored into an energy storage system, which is represented by the super capacitor.

The input of the DC to DC converter is from the harvested rectified sources, which are known to be low voltage; typically less than 1 V. Thus, in order to reduce the power losses, the component selection is crucial to ensure that the output power from the DC to DC converter is still sufficient to power up the low power applications.

1.6 Organisation of the Research work

Chapter 1 contains the motivation for the work and the main contributions to the field. The objectives as well as the project scope are also presented to give an overview of the research.

Chapter 2 gives more details on the literature work in a broader context. The chapter reviews past literature on energy harvesting, basic AC to DC converter circuit and the selection of the DC to DC converter as well as the energy storage system comparison.