ENERGY ADAPTIVE POWER MANAGEMENT SYSTEM USING MPPT TECHNIQUES FOR ENERGY SCAVENGING IN MOBILE AND WIRELESS DEVICES

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ABSTRACT

Energy harvesting has grown from long-established concepts into devices for powering ubiquitously deployed sensor networks and mobile electronics. Systems scavenge power from human activity or derive limited energy from ambient heat, light, radio, or vibrations. The radio frequency (RF) energy harvesting is developed by the wireless energy transmission technique for harvesting and recycling the ambient RF energy that is widely broadcasted by many wireless systems such as mobile communication systems, Wi-Fi base stations, wireless sensor networks and wireless devices. In this paper, a power management system has been designed and developed for performing maximum power point tracking (MPPT) techniques as the fluctuation of the input power across the target frequency range. The MPPT techniques implemented are the perturbation and observation (P&O) and fractional open circuit voltage (FOCV). The analog MPPT circuit controlled the charging and discharging stage by the duty cycle which depends on the variation of harvested power. The circuit is simulated and designed using standard 0.13µm Silterra process technology. The comparator of the MPPT circuit is optimized by parametric optimization and the layout of comparator is constructed in Synopsis software. Several layout design rules are applied in order to ensure accurate result for the circuit design. Moreover, a digitally control MPPT circuit which controlled by microcontroller unit (MCU) is constructed to control the different operation stages and generate maximum power point. The techniques that implemented in digital MPPT circuit is P&O algorithm which is the same algorithm as the proposed analog MPPT circuit.

ABSTRAK

Penuaian tenaga telah berkembang daripada konsep lama wujud dalam peranti untuk menjanakan rangkaian sensor ubiquitously dikerahkan dan elektronik mudah alih. Systems hapus sisa kuasa dari aktiviti manusia atau memperoleh tenaga yang terhad daripada haba ambien, lampu, radio, atau getaran. Frekuensi radio (RF) penuaian tenaga dibangunkan oleh teknik penghantaran tenaga tanpa wayar untuk penuaian dan kitar semula tenaga RF ambien yang meluas disiarkan oleh banyak sistem tanpa wayar seperti sistem mudah alih komunikasi, stesen pangkalan Wi-Fi, rangkaian sensor tanpa wayar dan peranti tanpa wayar. Dalam kertas ini, sistem pengurusan kuasa telah direka dan dibangunkan untuk melaksanakan teknik maksimum titik kuasa pengesanan (MPPT) sebagai turun naik kuasa input seluruh julat frekuensi sasaran. Teknik-teknik MPPT dilaksanakan ialah usikan dan pemerhatian (P&O) dan pecahan voltan litar terbuka (FOCV). Litar MPPT analog mengawal pengecasan dan peringkat melaksanakan dengan kitar tugas yang bergantung kepada perubahan kuasa dituai. Litar ini akan disimulasikan dan direka menggunakan teknologi 0.13µm proses Silterra. Comparator litar MPPT dioptimumkan oleh pengoptimuman parametrik dan susun atur comparator telah dibina dalam perisian Synopsys. Peraturan reka bentuk beberapa susun atur digunakan untuk memastikan keputusan yang tepat untuk reka bentuk litar. Selain itu, mengawal secara digital litar MPPT yang dikawal oleh unit pengawal mikro (MCU) dibina untuk mengawal peringkat operasi yang berbeza dan menjana titik kuasa maksimum. Kaedah yang dilaksanakan litar MPPT digital adalah P&O algoritma yang menggunakan algoritma sama seperti litar analog MPPT yang dicadangkan.

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RF	-	Radio Frequency	1
IoT	-	Internet of Things	5
MPPT	-	Maximum Power Point Tracking	5
DRC	-	Design Rule Check	6
LVS	-	Layout Versus Schematic	6
PEX	-	Practices Extraction	6
GDSII	-	Graphic Database System Stream Format File	6
MOSFET	-	Metal-Oxide-Semiconductor-Field-Effect Transistor	7
CMOS	-	Complementary Metal-Oxide Semiconductor	9
DSP	-	Digital Signal Processor	13
MPP	-	Maximum Power Point	13
P&O	-	Perturbation and Observation	17
FOCV	-	Fractional Open Circuit Voltage	17
DTCM	-	Design Time Component Matching	17
P-MOS	-	P-Type Metal-Oxide Semiconductor	32
N-MOS	-	N-Type Metal-Oxide Semiconductor	32
PMC	-	Power Management Circuit	32
Wp	-	Width of P-Type Transistor	35

Lp	-	Length of P-Type Transistor	35
Wn	-	Width of N-Type Transistor	35
Ln	-	Length of N-Type Transistor	35
m^{-1}	-	Current Perturbation	49
m	-	Next Perturbation	49
clk	-	Clock Signal	49
cmd	-	Comparator Output	49
Q1	-	First Flip Flop Output	49
Q2	-	Second Flip Flop	49
MCU	-	Microcontroller Unit	59
PWM	-	Pulse Width Modulation	64
DfE	-	Design for Environment	66
OEM	-	Original Equipment Manufacturer	66

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CHAPTER 1

INTRODUCTION

1.1 Project Background

Several environmental energy sources have been extensively investigated such as light, heat, vibration, and electromagnetic radiation from communication devices. These energy sources able to provide instantaneous power for low power electronics. For example, radio frequency (RF) energy scavenging from wireless electronics system has been widely used in wireless power transmission. In order to optimize the transfer of power into the application devices, an energy-adaptive maximum power point tracking technique is proposed to manage harvested low-level energy from different energy sources.

In this paper, the priority energy source chosen is RF energy source. The reason to choose RF as the priority energy source for the power management circuit is because the RF energy is ubiquitously existing in the surrounding. The main applications emphasized by this project is the mobile electronics and sensor devices, by wirelessly harvest energy from RF sources, the user able to charge the devices in anytime and anyplace. The energy harvesting energy from antenna and convert to dc sources by rectifier, eventually produce renewable energy from surroundings environment.

However, the energy harvested by RF harvesting system is still very small. The power management system needs to track the operating voltage which will generate maximum power output for the system in order to maintain the output at a maximum level [1]. In spite of the maximum power generation with power management techniques, the system will not suitable to be implemented when the amount of scavenged energy is small compared to that of consuming energy for the system operation [1]. The diagram below shows the typical energy harvesting sensor application. This paper focuses on the power management block and its interface to the rectenna and energy storage device [2]. In order to optimize the energy harvested, the power management system have to generate maximum output power.

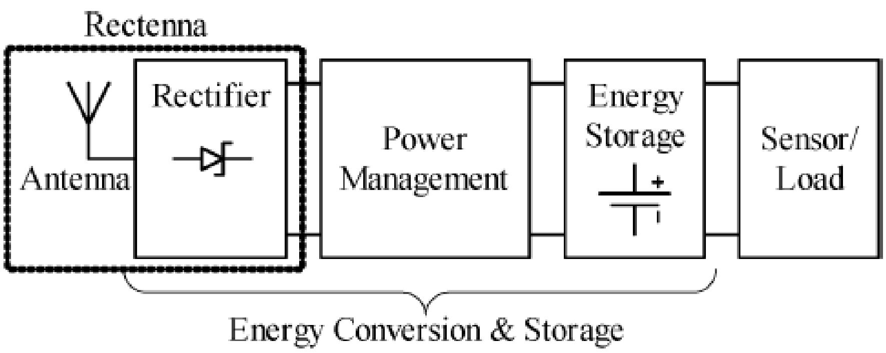

Figure 1.1: The diagram shows the typical energy harvesting sensor application

An energy harvesting system normally included components such as energy harvester or energy transducer, electrical power management or conditioning circuit, energy storage device and electrical load which are applications. The following section will discuss about the components in an energy harvesting system.

1.1.1 Transducer (Antenna)

The transducer will convert the harvested energy from energy sources such as solar energy, thermal energy, vibration or RF energy into electrical energy, by using an antenna, solar cell, a piezoelectric device, or other. The output that generated by the transducer can be in a DC form or in AC form depending on the energy source.

1.1.2 Power conversion (Rectifier)

The power conversion circuit can be a rectifier or DC-DC converter which can converts the provided energy into a suitable DC voltage. In the block diagram, the power conversion is a rectifier which convert RF energy to DC source. The efficiency of the circuit is an important factor which indicates the amount of the useful energy that can be utilized by the application.

1.1.3 Power management

Power conversion circuit usually have different level for available power depending on the application, the output voltage of the power conversion circuit can be regulated to a stable DC voltage using buck or boost converter or it can have limited by voltage limiter. The power management system controls the conduction path between the device and energy harvester. A good power management system can to generate the maximum power output for the energy storage or application devices.

1.1.4 Charge storage

The charge storage is used to keep the charge and store it in a capacitor or a rechargeable battery or other storage element. When selecting a rechargeable element, it is important to consider the ability of the battery/capacitor to withstand a high number of charge/discharge cycles and maintain its performance characteristics. Super-capacitors, traditional capacitors, and thin film batteries are known for their ability to retain performance even after a high number of charge/discharge cycles.

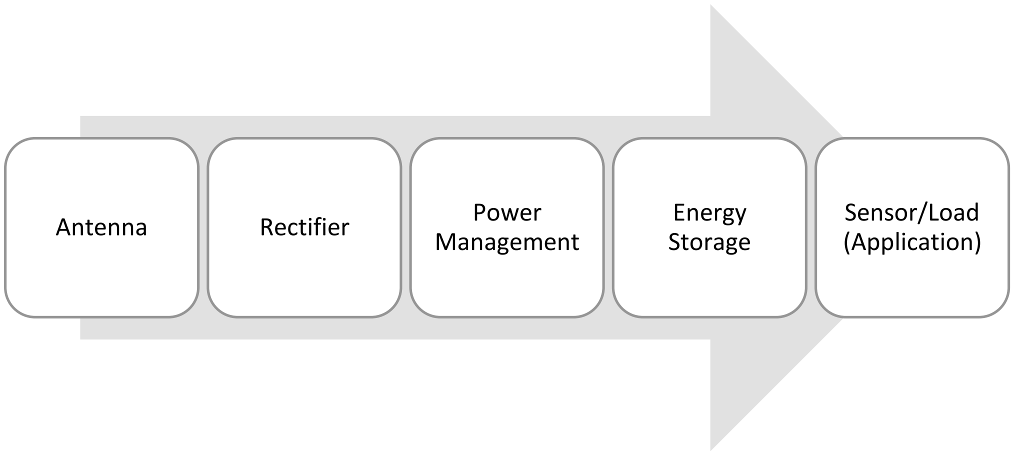

Figure 1.2: Block Diagram Flow shows steps that harvested energy transfer from Transducer to Load

Moreover, the system need to be energy adaptive, in order to generate constant outputs despite of the conditions of the harvesting environment changes as periodic changes and other reason, and the result maintains a new operating voltage of maximum power generation. The proposed power management system able to be adaptively manage the harvested energy when different level of voltage is harvest from the sources [2].

1.2 Problem Statement

Energy harvesting has grown from long-established concepts into devices for powering ubiquitously deployed sensor networks and mobile electronics. Systems can scavenge power from human activity or derive limited energy from ambient heat, light, radio, or vibrations. However, if the ubiquitous and sustainable energy sources are not use, the energy source will be a waste to the surrounding. As an example, the RF energy harvesting is developed by the wireless energy transmission technique for harvesting and recycling the ambient RF energy that is widely broadcasted by many wireless systems such as mobile communication systems, Wi-Fi base stations, wireless routers, wireless sensor networks and wireless portable devices. Also, the Internet of things (IoT) is the upcoming technology that will bring the communication between devices to the next level. In other words, IoT means there will be Internet everywhere, and overwhelmed with RF sources. RF energy harvesting is becoming the next generation trend for mobile electronics devices and wireless sensor system. Imagine the mobile devices able to harvesting energy to charge the battery while the user is using the devices or browsing a website by a smartphone. The harvesting will extend and improve the battery life for the devices and sensors without doubts.

In this project, a power management system will be designed and developed for performing maximum power point tracking (MPPT) as the fluctuation of the input power across the target frequency range. The power management system is a miniature integrated circuit, therefore it is able to implement in the application of mobile electronics or sensors. The proposed power management circuit will be fabricated. Before the fabrication process, the power management circuit will be designed in layout and tested by the standard verification tests.

1.3 Objectives

The objectives of the project included:

- To investigate techniques and construct adaptive power management system in miniature size.
- To design a power management system to manages low-level energy.
- To verify the functionality of the power management system that harvest energy from ubiquitous energy sources in sensor networks and mobile electronics.

1.4 Scope of Works

The project is to design an energy-adaptive MPPT power management unit for harvesting energy from low level power sources. Prior energy sources for the power management system is energy harvested by RF radiation, yet the power management unit will have focused on applications that consume power in the order of µW to mW or even higher in order to implement in more energy scavenging applications. The proposed power management system will manage input voltage sources by energy-adaptive MPPT technique, the energy harvested is able to be manage in high efficiency even when the power level is changed or switched from the harvesting sources.

The schematic circuit design and layout design will be construct by using the software Synopsis Custom Design. The completed circuit will be tested by verification test included DRC (Design Rule Check), LVS (Layout Versus Schematic), and PEX (Practices Extraction). A GDSII file will be created after the verifications tests.