DESIGN AND DEVELOP AN ENERGY HARVESTING CIRCUIT

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Faculty of Electronics and Computer Engineering

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Special thanks to my family, project supervisor, friends and other staffs in UTeM

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ABSTRACT

Limited life span of the battery usually limits the operating time of the devices in wireless sensor network (WSN). Although solar energy harvesting could be one of the ways to solve the problem, but due to the blackout period and weather problem, it becomes not practical. Therefore, Radio Frequency (RF) energy harvesting can be an alternative to solve this problem. Nowadays, there are a lot of wireless communication network exists in the world such as mobile network, WiFi and satellite communication network. RF energy is one of the energy sources where it is essentially inexhaustible. It is time independent and a kind of easily obtained energy source. RF energy harvesting system can be used to convert the RF energy to an amount of electrical energy that is possible to power up an application in wireless sensor network. RF energy harvesting system makes wireless sensor network becomes more practical in cost, size and lifespan. In this project, an RF energy harvesting system that is operating at 915MHz is designed. With the use of direct RF input, 50.42% of power conversion efficiency at -5dBm is achieved. On the other hand, with the use of receiving antenna, 23.06% of the power conversion efficiency at -5dBm is achieved as well. The RF energy harvesting system is designed by using the Advanced Design System (ADS) software. Then, the layout design of the RF energy harvesting system is design by using the Momentum Software. The process is followed by developing the harvester by using off the shelf components. Lastly, the overall simulation result and the experimental result has been recorded, analyzed and discussed clearly as well.

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ABSTRAK

Jangka hayat terhad bateri biasanya menghadkan masa operasi peranti dalam rangkaian sensor tanpa wayar. Walaupun penuaian tenaga solar boleh menjadi salah satu cara untuk menyelesaikan masalah ini, tetapi disebabkan tempoh malam dan masalah cuaca, ia tidak menjadi praktikal. Oleh itu, Frekuensi Radio (RF) penuaian tenaga boleh menjadi alternatif untuk menyelesaikan masalah ini. Pada masa kini, terdapat banyak rangkaian komunikasi tanpa wayar wujud di dunia seperti rangkaian mudah alih, WiFi dan rangkaian komunikasi satelit. Tenaga RF adalah salah satu sumber tenaga di mana ia adalah pada dasarnya tidak akan habis. Ia bebas dari masanya dan adalah sejenis sumber tenaga yang mudah diperolehi. Sistem penuaian tenaga RF boleh digunakan untuk menukar tenaga RF kepada sejumlah tenaga elektrik yang mungkin untuk memberi kuasa kepada satu aplikasi dalam rangkaian sensor tanpa wayar. Sistem penuaian tenaga RF membuat rangkaian sensor tanpa wayar menjadi lebih praktikal dalam kos, saiz dan jangka hayat. Dalam projek ini, sistem penuaian tenaga RF yang beroperasi pada 915MHz direka. Dengan penggunaan input RF langsung, 50.42% daripada kecekapan penukaran kuasa di -5dBm dicapai. Sebaliknya, dengan penggunaan antena, 23.06% daripada kecekapan penukaran kuasa di -5dBm juga dicapai. Sistem penuaian tenaga RF direka dengan menggunakan Advanced Design System (ADS) Software. Kemudian, reka bentuk susun atur sistem penuaian tenaga RF direka dengan menggunakan Software Momentum. Proses ini diikuti dengan menghasilkan penuai dengan menggunakan komponen electronik. Akhir sekali, hasil simulasi keseluruhan dan hasil eksperimen juga telah direkodkan, dianalisis dan dibincangkan dengan jelas.

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TABLE OF CONTENTS

PROJECT TITLE	**i**
CONFIRMATION OF REPORT STATUS	**ii**
DECLARATION	**iii**
SUPERVISOR'S CONFIRMATION	**iv**
DEDICATION	**v**
ACKNOWLEDGEMENT	**vi**
ABSTRACT	**vii**
ABSTRAK	**viii**
TABLE OF CONTENTS	**ix**
LIST OF TABLES	**xii**
LIST OF FIGURES	**xiv**
LIST OF ABBREVIATIONS	**xviii**
LIST OF APPENDICES	**xix**
CHAPTER 1	**1**
INTRODUCTION	**1**

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1.1 Project Overview 1
1.2 Problem Statement 1
1.3 Objectives 2
1.4 Scope of Project 3
1.5 Significant of Study 3
1.6 Report Outline 3

CHAPTER 2 **5**

LITERATURE REVIEW **5**
2.1 Overview 5
2.2 RF Energy Harvesting 5
2.3 A Review on RF Basic Structure 7
2.4 Spectrum Harvesting 8
2.5 Friis Transmission Equation 10
2.6 Rectifier 11
2.6.1 Basic Rectifier 12
2.6.2 Voltage Doubler 14
2.6.3 Voltage Multiplier 15
2.7 Powercast P2110B RF Receiver 18
2.8 Summary 19

CHAPTER 3 **21**

METHODOLOGY **21**
3.1 Overview 21
3.2 The Process of the Development of RF Energy Harvesting Circuit 22
3.3 The Block Diagram of RF Energy Harvesting Circuit 23
3.4 Literature Review on RF energy Harvesting Circuit 24
3.5 System Specification 24
3.6 Transmitting and Receiving Antenna 24
3.7 Matching Network 26
3.8 Schematic Design 27

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3.9 Layout Design 31
3.10 Fabrication and Soldering Process 36
3.11 Summary 42

CHAPTER 4 **43**

RESULTS AND DISCUSSION **43**
4.1 Introduction 43
4.2 Transmitting Antenna and Receiving Antenna 43
4.3 RF Input Feed Line in Schematic Design 46
4.4 RF Input Feed Line in Layout Design 48
4.5 Measurement Result 51
4.5.1 Direct RF Input 51
4.5.2 RF Input by Using Antenna 55
4.6 Summary 60

CHAPTER 5 **61**

CONCLUSION AND RECOMMENDATION **61**
5.1 Overview 61
5.2 Project Summary and Conclusion 61
5.3 Recommendation 62
5.3.1 High Efficiency of the Receiving Antenna 63
5.3.2 Design for a Particular Application 63
5.3.3 Storage System 63

REFERENCES **64**

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LIST OF TABLES

NO TITLE PAGE

Table 2.1: Estimated Harvested Power from Various Energy Source 6

Table 2.2: Electromagnetic Frequency Spectrum with Example of the Application.. 8

Table 2.3: Pin Functional Description 19

Table 3.1: System Specification of the RF Energy Harvesting System..... 24

Table 3.2: Specification of the Receiving Antenna 25

Table 3.3: Specification of the Transmitting Antenna 25

Table 3.4: Recommended Dimensions of the 50 Ohms (CPWG) Feed Lines (mils) 26

Table 3.5: Recommended Dimensions of the 50 Ohms (CPWG) Feed Lines (mm) 27

Table 3.6: Microstrip Substrate Parameter..... 30

Table 3.7 The Pin and Its Each Function 32

Table 4.1 Return Loss of the Antenna 46

Table 4.2: The Dimension of the RF input Feed Line 47

Table 4.3: Dimension of the Transmission Line in Layout Design 48

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Table 4.4: Return Loss of the Transmission Line 50

Table 4.5 Measurement Results with Direct RF Input..... 52

Table 4.6: Measurement Result with the Use of Antenna 56

Table 4.7: Capacitor voltage at Certain Period of Time 59

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LIST OF FIGURES

NO TITLE PAGE

Figure 2.1Block Diagram of RF Energy Harvesting System..... 7

Figure 2.2: Free Space Propagation Model..... 10

Figure 2.3: Peak Detector..... 12

Figure 2.4: Output Waveform of Peak Detector 13

Figure 2.5: Full wave Rectifier 13

Figure 2.6: Waveform of Full wave Rectifier..... 14

Figure 2.7: Voltage Doubler Circuit 15

Figure 2.8: Dickson Multiplier..... 16

Figure 2.9: Villard Multiplier..... 16

Figure 2.10: 4 Stages of Voltage Multiplier..... 17

Figure 2.11: Six Stage Voltage Doubler Circuit 17

Figure 2.12 Functional Block Diagram of RF Receiver 18

Figure 2.13: Top View of Pin Configuration..... 18

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Figure 3.1: Flow Chart of the Proposed Project 22

Figure 3.2: Block Diagram of the Proposed Project 23

Figure 3.3: The Schematic Design of the Proposed System 28

Figure 3.4: Frequency Tab on the Harmonic Balance 29

Figure 3.5: Sweep Tab on the Harmonic Balance 29

Figure 3.6: Scattering Parameter Simulation Tab 30

Figure 3.7: Footprint of the Powercast RF Receiver 32

Figure 3.8: RF input Transmission lines 34

Figure 3.9: Layout Design in 2D View 35

Figure 3.10: Layout Design in 3D View 35

Figure 3.11: EM Simulation Setup for Substrate's Parameter 35

Figure 3.12: EM Simulation Setup for Ports 36

Figure 3.13: Layout in CorelDRAW 37

Figure 3.14: Printed Layout on A4 Paper 38

Figure 3.15 : Printed Layout on Transparency Sheet 38

Figure 3.16: UV Light Exposing Process 39

Figure 3.17: Image Developing Process 39

Figure 3.18: Washing the Residue 39

Figure 3.19: Etching Process 40

Figure 3.20: Circuit Board after Etching Process 40

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Figure 3.21: Drying Process 40

Figure 3.22: Circuit Board on Front View 41

Figure 3.23: Circuit Board on Back View 41

Figure 3.24: The Circuit Board after Soldering Process 41

Figure 4.1: Network Analyzer Used for the Return Loss Measurement 44

Figure 4.2: Measurement of Return Loss of Transmitting Antenna 44

Figure 4.3: Measurement of Return Loss of Receiving Antenna 45

Figure 4.4: Return Loss of the Transmitting Antenna 45

Figure 4.5: Return Loss of the Receiving Antenna 45

Figure 4.6: LineCalc Tab 46

Figure 4.7: Simulation Result of the Return Loss and the Insertion Loss of the RF Input Feed Line 47

Figure 4.8: S11 Result 49

Figure 4.9: S33 Result 49

Figure 4.10: S55 Result 50

Figure 4.11: Power Device 51

Figure 4.12: Interface of SynthHD 51

Figure 4.13: Measurement Setup 52

Figure 4.14: Graph of Output Voltage against Input Power 53

Figure 4.15: The Graph of Power Conversion Efficiency against the Input Power . 55

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Figure 4.16: Experiment Setup 56

Figure 4.17: The Graph of Output Voltage against the Input Power 57

Figure 4.18: The Graph of Conversion Efficiency against the Input Power 58

Figure 4.19: The Capacitor Voltage against Time 59

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LIST OF ABBREVIATIONS

WSN	-	Wireless Sensor Network
RF	-	Radio Frequency
DC	-	Direct Current
ADS	-	Advanced Design Software
GSM	-	Global System for Mobile Communications
WiFi	-	Wireless Fidelity
SMA	-	SubMiniature version A

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LIST OF APPENDICES

NO	TITLE	PAGE
A	Transmitting Antenna	67
B	Receiving Antenna	68
C	Powercast RF Receiver	69
D	SMA Straight Jack Port	71
E	Copper Clad Board	72
F	IEEE Paper	74

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CHAPTER 1

INTRODUCTION

1.1 Project Overview

RF Energy is one of the energy sources where it is essentially inexhaustible. It is time independent and a kind of easily obtained energy source. This essentially free energy source is maintenance- free. Besides, it is more practical in cost, size and lifespan. When RF energy harvester is designed and installed properly, it can be used to convert the RF energy to an amount of electrical energy that is possible to power up an IoT application or low power devices which is more reliable than using batteries. In this project, an RF energy harvesting system will be designed and developed based on off-the-shelf components. The system includes antenna, impedance matching network and rectifier DC load circuit. The system will be designed using the Advanced Design System (ADS) software.

1.2 Problem Statement

Energy is everywhere in the environment surrounding us which are available in the form of thermal energy, solar energy, wind energy, and mechanical energy.

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However, the energy from these sources is often found in such minute quantities that it cannot supply adequate power for any viable purpose. In practical wireless sensor usage, the need for a battery limits the application space and increases initial and recurring costs, making traditional wired sensors more appealing in some cases. When the usage of the battery has gradually increased, the deposition of the battery causes the environment pollution as well. The harmful chemical such as lead and lithium poses health issues to mankind and animals if the batteries are throwing to the landfills. Therefore, it comes to a solution where the solar energy harvesting is used for power up the wireless sensor. The use of solar energy in energy harvesting wireless sensor networks (WSNs) has increased for practical applications due to the higher energy density harvested as compared to other energy harvesting technique. However, solar power strongly depends on sunlight and therefore it is hardly to harvest energy during night time. Besides, the amount of the harvested energy depends on the weather as well. Therefore, in order to activate a sensor node during night time, it must be equipped with rechargeable batteries. These rechargeable batteries require extra recharging circuit and are usually expensive. Hence, RF energy harvesting can be an alternative and viable source of energy due to its availability at all hours and it is not depends on blackout period and weather. Due to the fact that in the modern environment, there are multiple wireless sources of different frequencies radiating power in all directions, thus, RF energy harvester can be considered as one of the best energy harvesting that can generate electrical power by using these unlimited sources.

1.3 Objectives

The main objectives of this project are:

(i) To design a RF energy harvesting circuit.

(ii) To develop a RF energy harvesting circuit.

(iii) To develop proof of concept RF energy prototype based on off-the-shelf components.

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1.4 Scope of Project

This project will cover the RF energy harvesting circuit design simulation and its prototype fabrication. The circuit design will be simulated by using Advanced Design System (ADS) software. Then, the desired schematic diagram is transformed to the layout in the electromagnetic simulator, Momentum. Off the shelf components such as antenna, RF receiver, capacitors, and resistors will be used as the system design. The RF energy harvesting circuit should be able to function at 915MHz and produce a stable DC output voltage and store it in a storage element. A laboratory experiment will be carried out to determine the functionality and performance of the prototype. The parameters involve in this project includes RF input power (dbm), output voltage (V), output power (W) and power conversion efficiency (%). Apart from that, antenna design is not covered in this project.

1.5 Significant of Study

This project will shows the capability of RF energy harvesting from the ambient electromagnetic energy produced by the radio telecommunication devices. Electromagnetic energy is ubiquitous in our daily life. Energy harvesting devices will utilize the power resources available in the surrounding. This is one of the alternative power sources for electricity and this renewable energy is most feasible. Thus, the battery lifetime problem and the burden of battery replacement of the wireless sensor network can be solved directly. Furthermore, this project will also helps in the growing demand of portable power devices where there are a lot of mobile devices that function by using battery that need a constant recharge. Therefore, this is another solution for battery fast drain problem where recharging process can be done wirelessly in anywhere and away from the power supply unit.

1.6 Report Outline

This thesis consists of five main chapters. It explains and discusses the details of each chapter as follow:

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Chapter 1 – Introduction

This chapter discusses about the introduction of this project. The introduction includes the project overview, problem statement, objectives of project, scope of project, significant of study and the report outline throughout the project.

Chapter 2 – Literature Review

This chapter consists of literature review. Any information or study related to the radio frequency energy harvesting will be further described, summarized, evaluated and discussed in this section. The literature review is based on the reference of previous study from other researchers.

Chapter 3 – Methodology

This chapter highlights the methodology of the project. In this section, the procedure of the design approach is elaborated and the implementation of the project is clearly explained.

Chapter 4 – Results and Discussions

This chapter consists of the results and discussion of the project. This chapter focuses on the simulation and the measurement results. The experiment setup and the measurements result of the completed prototype are introduced to test for its functionality. Then, the results and findings are compared and discussed in this chapter as well.

Chapter 5 – Conclusion and Recommendation

The last chapter concludes the overall results of the project and examines either the objectives of the project are fulfilled. The recommendation and the future works of this project are also proposed in this section.

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CHAPTER 2

LITERATURE REVIEW

2.1 Overview

This chapter discusses about the concept of the radio frequency energy harvesting and the related information regarding to the previous work from other researchers.

2.2 RF Energy Harvesting

Energy is everywhere in the environment surrounding us. Energy is available in the form of thermal energy, solar energy, mechanical energy and wind energy. There is a lot of active research in investigating alternative ways to capture energy from environment. Advanced technical developments have increased the efficiency of devices in capturing trace amounts of energy from the environment and transforming them into electrical energy. These developments have sparked the interest in the engineering community to develop more and more application that utilizes energy harvesting for power. One of the energy harvesting sources for power

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