UNIVERSITI TEKNOLOGI MARA

COMPACT SINGLE-STAGE INPUT-POWERED BRIDGE RECTIFIER WITH BOOST SWITCH WITH HIGH OUTPUT POWER FOR ENERGY HARVESTING SYSTEM USING 0.18-MICRON CMOS TECHNOLOGY

ROSKHATIJAH RADZUAN

Thesis submitted in fulfillment
of the requirements for the degree of
Doctor of Philosophy

Faculty of Electrical Engineering

January 2017

ABSTRACT

The demand on microwatt to milliwatts energy harvesting systems has been increasing recently with the increase of the needs for wireless self-powered device applications. With the small output voltage and the AC output from the micro harvesting generators, highly precise specifications, leading to challenging designs, optimizations and realizations of its every component are imposed. Rectifier, which is normally located right after the energy generator in the energy harvesting system, is required to be compact, with high efficiency to produce as high output power as possible. It is in this context that this thesis is focusing, where a new topology of CMOS bridge rectifier is proposed, offering advantages in terms of the compactness and high output power, which is suitable for wireless power devices applications. CMOS technology is seen as a straightforward solution for compactness as it offers possibility to reduce the full wave rectifier circuit size. The proposed rectifier circuit topology is designed such that the threshold voltage, which is a common source of voltage drop in the system, can be reduced, in order to maintain high output voltage. A boost switch is also integrated in the topology, to play the main role in the system voltage doubler, which is much simpler and requires lesser external connections as compared to other recent topologies. Powered by its input AC voltage, the overall circuit will be implemented using 0.18-micron CMOS process technology with low threshold voltage. The analysis of the MOS-based circuits is performed through numerous designs and simulations using simulation tools. Measurement and testing of the prototypes are carried out using DC-DC probes to validate the proposed idea and concept. While providing 1.272 V dc output voltage across a 2 kΩ resistive load from 1.0 V peak AC input voltage at 50 Hz, the proposed bridge rectifier with boost switch achieved the measured output power of 1.65 mW. The proposed rectifier topology implemented on the highly rated CMOS technology is proven to offer compact and efficient solutions to further enhance the energy-harvesting domain of technology. With the overall active surface area of 0.024 mm^2 and with only six external connections, the proposed rectifier design is found to be more compact than other reported rectifiers to date.

ACKNOWLEDGEMENTS

It is both my pleasure and obligation to acknowledge generous people who have provided me with guidance and inspire me to make this happen. I would like to thank my supervisor, Dr. Mohd Khairul bin Mohd Salleh for valuable guidance, critics, encouragement and support throughout this program. It is truly impossible to express my feeling of gratitude in mere words.

I would also like to acknowledge my sincere, appreciation and gratitude to Tuan Haji Mustafar Kamal Hamzah who is my co-supervisor, for his continue support, advices and guidance in completing this thesis. Special thanks go to Prof Dr Mohamad Rusop Mahmood, who is my second co-supervisor for idea and advice throughout the project.

My friends and fellow colleagues, thank you for being good teammates throughout this course of work. Your assistance, views and tips are treasured in my heart.
Never can I forget my family for being instrumental, cherish, motivating and more importantly for their patience throughout this period. To them, I remain grateful and nor can I ignore them from my memory. I would never have been able to complete this thesis when I did if ever at all.

Finally, this thesis is dedicated to my beloved husband, Syamsuri Bin Ya'acob for your love, patience, kindness and full support over the entire period of my study and my sweet and loving mother, who affection, love, encouragement and prays of day and night make me able to get such success and honor. Last and absolutely not least, my one and only daughter Afnan Nisrina Binti Syamsuri thanks for all your love, lots of cares and happiness.

TABLE OF CONTENT

CHAPTER ONE
INTRODUCTION

1.1 BACKGROUND OF THE STUDY

The trend in the use of the wireless sensor and portable electronic devices has emerged rapidly. Several advantages include; flexibility, ease of implementation and ability to facilitate the placement of sensor devices in a small space [1][2][3]. These electronic devices rely on the utilization of the electrochemical battery for providing electrical energy as power source with the main disadvantage of limited lifespan requiring their periodic replacement [4][5][6][7]. Figure 1.1 shows the performance of mobile computing systems compared with battery technology on a logarithmic scale of energy density since 1990 [8]. The growth of battery technology has remained the slowest by a mere three-fold increase over the past decade, while the performance of the computing systems has grown steadily over 250 times [8].

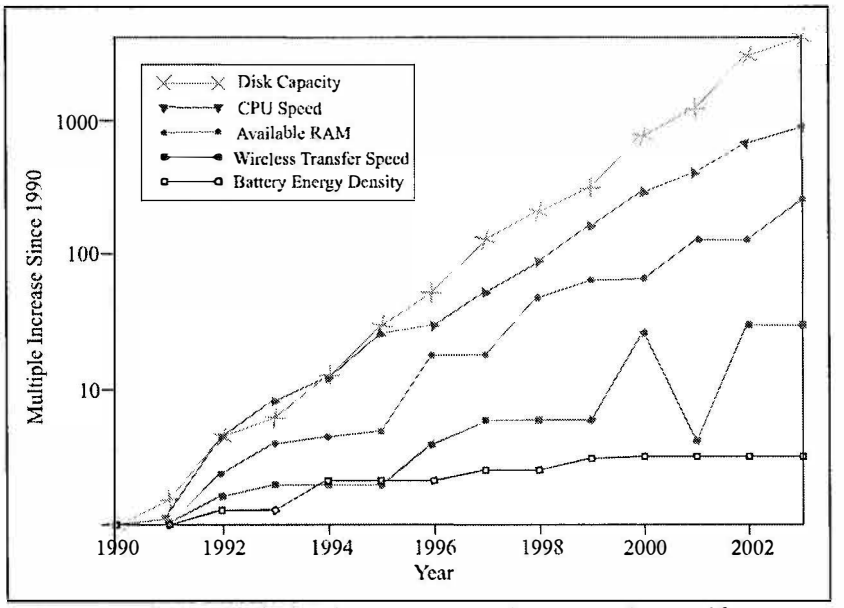

Figure 1.1 Relative improvements in computing and battery technologies since 1990 [8]

In recent years, microwatt to milliwatts vibrational energy harvesting technology has progressed enormously, encouraging the development of wireless self-powered systems [9][10]. Due to the small output voltage [3] and the need to rectify