Environmental Noise Harvester For Low Voltage Power Supply

by

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A thesis submitted in fulfillment of the requirements for the degree of Doctor of Philosophy

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UNIVERSITI MALAYSIA PERLIS
2018

ACKNOWLEDGMENT

First of all, I thank God that He has given me the strength and wisdom to complete this PhD thesis. It is by His blessing and providence that I am able to solve the obstacles along the way and finish the research and thesis.

I would like to express my deepest gratitude to my supervisor Dr. Rosemizi Abd Rahim and also ex- supervisor, Professor Dr. Syed Idris Syed Hassan for his supervision over this work. His encouragement and guidance have always helps me to grow in knowledge and passion for my study. Not forgetting my co-supervisor, Associate Professor Dr. Muzamir Isa, Dr. Baharuddin Bin Ismail and Associate Professor Dr. Mohd Fareq Abd. Malek and for their inputs and assistance in helping me to complete this thesis.

I would like to take this opportunity to express my appreciation to the Dean of School of Electrical Systems Engineering, Dr. Haziah for his support in this study. I also want to thank Ir. Dr. Dina Maizana for their kindness and assistance throughout the laboratory work of this research. I would also like to express my gratitude to the rest of the academic staffs and technical staff in School of Electrical Systems Engineering who in one way or another had contributed and assisted in this project.

My sincere thanks go to my friends, Loh Huang Sheng and colleagues for their accompanies, support and constructive discussions that aided me throughout the research. I would like to highly appreciate the Malaysian Ministry of Higher Education for providing the Fundamental Research Grant Scheme (FRGS) for their financial support. Many thanks must go to Universiti Malaysia Perlis (UniMAP) for the academic support.

Last but not least, I would like to thank my family members for their unfailing love and moral supports. They have never ceased to encourage me and motivate me all the time.

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LIST OF ABBREVIATIONS

ABS	Acrylonitrile, Butadiene, and Styrene
AC	Alternating Current
AlN	Aluminium Nitride
AlO-rGO	Flexible Nanocomposite
BF	Bias-Flip
BJTs	Bipolar Junction Resistor system
CMOS	Complementary Metal-Oxide-Semiconductor
DC	Direct Current
DCM	Discontinuous Mode
DSSH	Double Synchronized Switch Harvesting
dB	Decibel
EAI	Energy Aware Interface
ECs	Electrochemical Capacitors
EDLCs	Electric Double Layer Capacitors
EH	Energy Harvesting
EMHR	Electrometrical Helmholtz Resonator
EMF	Electromotive Force
ESSH	Enhanced Synchronized Switch Harvesting
ESR	Equivalent Series Resistance
ESU	Energy Storage Unit
F	Farad
FB	Full Bridge
FBDR	Full Bridge Diode Rectifier
Fe	Ferro
Ge	Germanium
g	gram
Hz	Hertz
Hr	Hour
HV	High Voltage
IC	integrated Circuit

I/O	Input/Output
JFET	Junction Field-Effect Transistor
Kg	kilogram
Km	kilometer
KW	KiloWatt
LED	Light Emitting Diode
LIB	Lithium-ion Battery
M	Mega
m	Meter
mAh	milli-ampere hour
MEMS	Micro-electro Mechanical System
MFC	Macro Fiber Composite
MOSFET	Metal-Oxide-Semiconductor Field Effect Transistor
MPPT	Maximum Power Point Tracking
Mo	Molybdenum
mm	Millimeter
MnZn	Manganese and Zinc
mW	milliWatt
mV	millivolt
nV	nanoVolt
nF	nanoFarad
n/a	Not applicable
Ni	Nickel
NiMH	Nickel Metal Hydride
NMOS	Complementary Metal-Oxide-Semiconductor (N-Channel)
PCB	Printed Circuit Board
PCE	Power Conversion Efficiency
PEHs	Piezoelectric Energy Harvesting system
pk-pk	Peak to peak
PMM	Power Management Module
PMN	Lead Magnesium Niobate
P-SSHI	Parallel Synchronous Switch Harvesting on Inductor
PT	Piezoelectric Transformer

PT	Lead Titanate
PVDF	Polyvinylidenefluoride
PWM	Pulse Width Modulation
PZN	Lead Zirconate Niobate
PZT	Lead Zirconate Tittanate
RF	Electromagnetic Interference
RFID	Radio Frequency IDentification
rpm	Revolutions per Minutes
rms	Root Mean Square
SCRs	Silicon Controlled Rectifiers
SECE	Synchronous Electric Charge Extraction
Si	Silicon
SiO_2	Silicon dioxide
SPL	Sound Pressure Level
STM	Semiconductor Technology Microelectronics
SSDCI	Synchronized Switching and Discharging to a Capacitor through an Inductor
SSDI	Synchronized Switch Damping on Inductor
SSHI	Synchronous Switch Harvesting on Inductor
S-SSHI	Series-Synchronous Switch Harvesting on Inductor
SHE	Sound Energy Harvesting
TEGs	Thermoelectric Generators
μF	microFarad
μW	microWatt
VD	Voltage Doubler
VSSHI	Velocity Synchronous Switch Harvesting on Inductor
Wh	Watthour
WSN	Wireless Sensor Network
WSNs	Wireless Sensor Network system

LIST OF SYMBOLS

A	Flange diameter
a	Length side square
A_c	Cross-sectional area
B	Barrel
B_x	Tesla
C	Clearance
C_p	Parasitic capacitor
C_{sup}	Capacitance of supercapacitor
C_{piezo}	Capacitance piezo
$\{c^E\}$	Elastic coefficients
D	Arbor hole Diameter
D_c	Diameter of circle
D_o	Internal Diameter Roll
D_1	External Diameter Roll
{D}	Electric Displacement Vector
E	Total Energy
{E}	Electric Field Vector
{e}	Dielectric Permittivity matrix
f	Vibration frequency
$f_{bandwidth}$	Bandwidth frequency differ between higher and lower frequency
H	Height
h	Size of copper wire
$I_{charging}$	Charging Current
I_{in}	Input Current
I_{out}	Output Current
I_{sc}	Short Circuit Current
kΩ	Kilo-ohm
L	Total length of the tape
l	Length of winding turn
N	Number of turns

n	Efficiency
P	Perimeter
P_{in}	Input Power
P_o	Internal Perimeter
P_{out}	Output Power
P_1	External Perimeter
ρ	resistivity
Q	Coulombs Charge
R	Load Resistance
R_{opt}	Optimum Resistance Load
R_{dc}	Direct Current Resistance
R_{ESR}	Internal Resistance of Supercapacitor
R_p	Parasitic resistor
r	Radian of copper wire
{S}	Strain Vector
$\{\alpha^s\}$	Dielectric Matrix
s	Second
{T}	Stress Vector
τ	Total Time constant
T	Traverse
$t_{charging}$	Time charging
V_{dc}	Direct Voltage
V_{emf}	Electromotive Force Voltage
V_{in}	Input Voltage
V_k	Forward Voltage
V_{max}	Maximum voltage at center frequency of bandwidth graph
V_m	Max Voltage/ Peak voltage
V_{oc}	Open Circuit Voltage
V_{out}	Output Voltage
$V_{out(p)}$	Peak Output Voltage
V_{pk}	Peak voltage
V_{pk-pk}	Peak to peak voltage
V_{rms}	Voltage Root Mean Square

V_{sup}	Voltage rating of Supercapacitor
W	Overall Width
Z_i	Internal Impedance

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ABSTRACT

There is an increased awareness nowadays regarding the potential shortage of fuel sources for electricity generation in the future, where various studies have been conducted about the usage alternative sources. Currently, the renewable energy has been prioritized for instance, through ambient energy scavenging. To achieve this goal, sound, being the most abundant energy in the environment, is likely the best candidate to fill the slot. The existing rectifying technique that has been used for energy transfer in energy harvesting is 'switch-only' and 'bias-flip' techniques which is utilize an additional switches or switched inductors for speedy voltage rectification. However, such techniques depend on the timing accuracy and synchronization of the pulses of the switch whenever the changes in the currents' polarity generated by the piezoelectric harvester. The existing acoustics-based energy harvesting systems utilized a self-powered active rectifying diode circuitry technique to converts alternating current signal to direct current. The active MOSFET rectifier circuit has extra components and required an external DC supply to powering the rectifying circuit. Thus it is not a good option for small scale harvester system and suffered some drawbacks in the implementation of the circuit. Although synchronous switch harvesting on the inductor (SSHI) and synchronous electric charge extraction (SECE) rectifiers possess high efficiency to extract and harvest the energy available from system, they have drawbacks of SSHI circuits such as the complexity of the circuit which is can contribute to additional losses of power, threshold voltages, frequency selectivity and parasitic bandwidth filters. In this study, the developments of passive circuit including voltage multipliers (Dickson and Villard circuits) and step-up transformer were proposed and designed to rectify the low voltage acoustic voltage. The simulation of the proposed harvesting circuit was performed using Multisim and Portus simulator. For verification purpose, the PZT-5A piezoelectric transducer model has been chosen as the harvester due to the consistency. During the experiment, the resonance frequency of the harvester system was at 68 Hz with the 95 dB of acoustic pressure. The experimental results showed that the output closed-circuit voltage and the output power harvester can reach up to 3.894$V_{rms}$and 1.556mW respectively. The passive AC-DC harvesting circuits can probably achieve the overall energy conversion efficiency by 78.9% (Dickson circuit) (1.228mW), 70.5% (Villard circuit) (1.097mW), and 10.1% (step-up transformer) (0.1564mW) respectively. Based on the results presented above, the proposed energy harvesting systems seem to be promising and possess a good potential to be used in low power sensors such as wireless sensor networks.