SIMULTANEOUS MULTI-SOURCE INTEGRATED ENERGY HARVESTING SYSTEM FOR IOE APPLICATIONS

By

Mohamed Badr Mahmoud Mohamed Badr

A Thesis Submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfillment of the
Requirements for the Degree of
MASTER OF SCIENCE
in
Electronics and Communications Engineering

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Under the Supervision of

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Title of Thesis:

Simultaneous Multi-Source Integrated Energy Harvesting System for IoE Applications

Key Words:
Dickson Charge Pump; MPPT; Energy Harvesting; Hill-Climbing Algorithm; IoE

Summary:
This work presents an integrated modular multi-source energy harvesting system based on the Dickson charge pump and hill-climbing algorithm. The proposed maximum output power extraction is optimizing the system's end-to-end efficiency. It collects the power simultaneously from multiple energy sources and boosts their DC voltages to a regulated output voltage that can be used for Internet of Everything (IoE) applications. The proposed implementation utilizes the whole on-chip capacitance regardless of the number of stages in use. A demonstration system using the proposed techniques is implemented for two sources in 0.18 μm CMOS technology and it utilizes a total of 900 pF MIM capacitance. The simulation results show that the proposed system achieves a peak MPPT efficiency of 90%, charge pump efficiency of 70%, and end-to-end efficiency of 55% at a regulated output voltage of 1.5 V.

Disclaimer

I hereby declare that this thesis is my own original work and that no part of it has been submitted for a degree qualification at any other university or institute.

I further declare that I have appropriately acknowledged all sources used and have cited them in the references section.

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In the name of Allah, The Greatest and The Most Merciful.

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List of Symbols and Abbreviations

Symbol	Description
η_{e2e}	End-to-end Efficiency
η_{MPPT}	MPPT Efficiency
η_{CP}	Charge Pump Efficiency
α	Parasitic Capacitance Ratio
μ_n	Electron Mobility
μ_p	Holes Mobility

Abbreviation	Description
APR	Automatic Place and Route
CMOS	Complementary Metal Oxide Semiconductor
CP	Charge Pump
CTAT	Complement To Absolute Temperature
DCO	Digitally Controlled Oscillator
FSM	Finite State Machine
IoE	Internet of Everything
IOT	Internet of Things
MIM	Metal Insulator Metal
MOS	Metal Oxide Semiconductor
MOSFET	Metal Oxide Semiconductor Feild-Effect Transistor
MPP	Maximum Power Point
MPPT	Maximum Power Point Tracking
OTA	Operational Transconductance Amplifier
PCB	Printed Circuit Board
PMU	Power Management Unit
PTAT	Proportional To Absolue Temperature

PV	Photovoltaic
PVT	Process Voltage Temperature
PWM	Pulse Width Modulation
RTL	Register Transfer Level
SC	Switched-Capacitor
TEG	Thermoelectric Generation
WSN	Wireless Sensor Nodes
f_{osc}	Oscillation Frequency
N	Number of Stages
P_{av}	Available Power
P_{in}	Input Power
P_{out}	Output Power
R_{in}	Input Resistance
R_{out}	Output Resistance
V_{in}	Input Voltage
V_{out}	Output Voltage
V_{pp}	Peak to Peak Voltage
V_{ref}	Reference Voltage
V_s	Source Voltage

List of Publications

1. Mohamed Badr, Mohamed M. Aboudina, Faisal A. Hussien, Ahmed N. Mohieldin. "Simultaneous Multi-Source Integrated Energy Harvesting System for IoE Applications." in *2019 IEEE 62nd International Midwest Symposium on Circuits and Systems (MWSCAS)*, IEEE, 2019.