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Power Management for Wearable Electronic Devices

 Springer

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*The authors would like to dedicate this work
to their parents, families, and beloved ones*

Preface

With the dramatic rise of mobile electronic devices usage especially as an effect of the internet-of-things revolution, the demand for energy efficient and small form factor systems raises the need for low power multisource management unit (PMU) for energy strained devices as well as energy harvesting as alternative power source in many usage scenarios. Energy harvesting becomes one of the pillars that fulfill the needs of ultra-low power devices in many applications including the IoT-based healthcare. Since the harvested energy depends on the availability of various sources from the surroundings, a power management unit (PMU) is required to efficiently regulate the harvested energy.

Power converters and voltage regulators are important building blocks in the PMU in order to interface between the energy harvesting and the system on chip (SoC). Different types of energy harvesting source require different power converters. This depends on the electrical signal obtained from the harvester, harvester size, and efficiency. In addition, the selection of the voltage regulator depends on the area of the whole device and the requirements of various blocks in the SoC such as memory, hardware accelerator, analog front-end, and RF. Hence, sophisticated PMU circuits and techniques are required to enable the development of the state-of-the-art energy harvesting-based PMU including power converters and voltage regulators.

To accomplish this need, this book provides a comprehensive power management circuit design that targets low power wearable electronic devices powered by a thermoelectric generator (TEG) source, a battery or both. This includes extensive literature review about power converters and voltage regulators in addition to experimental results from silicon. This book is organized into 6 chapters. Each chapter carries a brief introduction of the work undertaken and is followed by the detailed circuit, results, and analysis.

Chapter 1 provides detailed background about the power management techniques at technology, circuit, and system level and delivers an overview of the recent energy harvesting source utilized for wearable electronic devices.

Chapter 2 discusses the basic concept of the TEG device and model and how it can harvest the thermal energy based on the Seebeck effect. Further, it provides a

comprehensive literature review about the interface circuits required by the TEG-based PMU such as power converters, startup circuits, voltage regulators, and maximum power point tracking technique. In addition, it presents the state-of-the-art TEG-based PMU designs that are available in the literature.

Chapter 3 focuses on the characterization of the system level TEG-based PMU using several design options of power converters and voltage regulators. The characterization in terms of power efficiency, voltage ripple, and area are based on measurement results in 65 nm CMOS technology which guides the researchers to select the proper PMU design based on the blocks' requirements within the device.

Chapter 4 highlights the state-of-the-art multi-outputs switched capacitor voltage regulators. Then, it discusses a dual-outputs switched capacitor (DOSC) voltage regulator using a single switched capacitor design in order to minimize the area of PMU. It highlights how the control circuit of adaptive time multiplexing can be used to generate two output voltage levels and eliminate the reverse current problem. Measurement results are shown in 65nm CMOS technology.

Chapter 5 provides a detailed literature review on the available digital low drop out (LDO) regulator. Then, it introduces a clock-less digital LDO regulator based on a ratioed logic comparator (RLC). Simulation results are shown in 22nm FDSOI technology and a comparison with prior work on digital LDO is illustrated.

Finally, Chap. 6 concludes this book and presents possible directions for future work in this area of research.

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Contents

1	Introduction to Power Management	1
1.1	Low Power Wearable Electronic Devices	1
1.2	Low Power Management Techniques	3
1.2.1	Dynamic Power Reduction	3
1.2.2	Leakage Power Reduction	5
1.3	Energy Harvesting-Based Device	9
1.4	Aim and Objectives	11
	References	12
2	Introduction to TEG-Based Power Management Unit	15
2.1	Introduction to TEG	15
2.2	Interface Circuit of TEG	17
2.2.1	Startup Circuit	17
2.2.2	DC–DC Boost Converter	18
2.2.3	Maximum Power Point Transfer Techniques	20
2.2.4	Voltage Regulator	21
2.3	Existed TEG-Based Power Management Solutions	25
	References	28
3	TEG-Based Power Management Designs and Characterizations	31
3.1	Proposed TEG-Based PMU Architecture	31
3.1.1	Switched Inductor Boost Converter Circuit Design	33
3.1.2	Switched Capacitor Regulator Circuit Design	33
3.1.3	LDO Regulator Circuit Design	35
3.2	TEG-Based PMU Measurements in 65 nm CMOS	36
3.3	Summary and Recommendations	45
	References	46
4	Dual-Outputs Switched Capacitor Voltage Regulator	47
4.1	State of the Art Dual-Outputs Switched Capacitor Voltage Regulator	47

- 4.2 Proposed Dual-Outputs Switched Capacitor Voltage Regulator 50
 - 4.2.1 Reconfigurable SC Circuit Design 51
 - 4.2.2 ATM Implementation 56
 - 4.2.3 Clocked Comparator 59
 - 4.2.4 Ring Oscillator 59
 - 4.2.5 Deadtime Phase Generator Circuit 60
- 4.3 Measured Results of DOSC Regulator in 65 nm CMOS Technology 60
- 4.4 Multi-Outputs Switched Capacitor Voltage Regulator 67
- 4.5 Summary 69
- Appendix: Verilog Code of ATM 69
- References 70
- 5 Ratioed Logic Comparator-Based Digital LDO Regulator 73**
 - 5.1 State of the Art Digital LDO Regulator 73
 - 5.2 Proposed Ratioed Logic Comparator-Based Digital LDO Regulator 78
 - 5.2.1 Ratioed Logic Comparator-Based DLDO Circuit Design 78
 - 5.2.2 Enhanced RLC-DLDO 82
 - 5.3 RLC-DLDO Design Optimization 85
 - 5.4 Simulation Results of RLC-DLDO Regulator in 22 nm FDSOI 87
 - 5.5 Summary 92
 - Appendix: Derivation of Output Voltage of the Ratioed Logic Circuit 92
 - Low Output Voltage of Ratioed Logic Circuit 92
 - High Output Voltage of Ratioed Logic Circuit 93
 - References 94
- 6 Conclusions and Future Work 97**
 - 6.1 Conclusions 97
 - 6.2 Future Work 98
- Index 101**

Abbreviations

AFE	Analog Front-End
ATM	Adaptive Time Multiplexing
CMOS	Complementary Metal Oxide Semiconductor
DLDO	Digital Low Drop Out
DVS	Dynamic Voltage Scaling
LDO	Low Drop Out
PEG	Piezo Electric Generator
PFM	Pulse Frequency Modulation
PMU	Power Management Unit
RLC	Ratioed Logic Comparator
SC	Switched Capacitor
SI	Switched Inductor
SoC	System on Chip
TEG	Thermo Electric Generator