Preface

This book deals with the challenge of exploiting ambient vibrational energy, which can be used to power small and low-power electronic devices, e.g., wireless sensor nodes. Generally, particularly for low voltage amplitudes, low-loss rectification is required to achieve high conversion efficiency. In the special case of piezoelectric energy harvesting, pulsed charge extraction has the potential to extract more power compared to a full-bridge rectifier. Therefore, a fully autonomous CMOS integrated interface circuit for piezoelectric generators which fulfills these requirements is presented. This book covers three main aspects of the integrated interface circuit:

First of all, the book explains in detail the different circuit blocks on transistor level and highlights techniques to reduce the power consumption. Hence, only a very small fraction of the power delivered by the generator is wasted, which is extremely important in order to achieve a high overall harvesting efficiency, especially in case the piezoelectric generator outputs little power.

Second, the book analyzes the various loss mechanisms within the CMOS chip, such as conduction losses, switching losses, etc. Therefore, a mathematical method of approximating the conduction losses is presented, which reduces calculation effort and gives deep insight into the loss dependency on different parameters. A detailed breakdown of the actual chip losses identifies the most dominant loss mechanisms and gives ideas how these losses can be further reduced.

Third, since the performance of the CMOS chip strongly depends on the used power source, lot of effort is spent on investigating the interaction between the interface circuit and the piezoelectric generator. For accurate simulations, a model which takes into account this electromechanical feedback is used. A CMOS chip has been fabricated and tested under laboratory conditions in combination with one custom-made and one commercially available piezoelectric generator. By comparing measurement and simulation results, the used model could be verified.

The presented CMOS chip has been shown to be fully autonomous and self-powered down to a piezoelectric output power in the range of 10 μW. It enables cold-startup and enhances the extracted power compared to the commonly known diode rectifiers by up to 127 %, depending on the excitation conditions. For low excitations, due to the boosting effect, the chip harvests power where a diode rectifier would harvest nothing. The chip operates properly for piezoelectric voltage amplitudes in the range of 1.3–20 V and for excitation frequencies from 50 Hz to 2 kHz.

Due to these key properties enabling universal usage, other CMOS designers working in the field of energy harvesting will be encouraged to use some of the shown structures for their own implementations. The book highlights the design process from scratch to the final chip. Therefore, it gives the designer a comprehensive guide of how to

- setup an appropriate harvester model to get realistic simulation results,
- design the integrated circuits for low power operation,
- setup a laboratory measurement environment in order to extensively characterize the chip in combination with the real harvester,
- and finally interpret the simulation and measurement results in order to improve the chip performance.

Since the dimensions of all devices (transistors, resistors etc.) are given, readers and other designers can easily re-use the presented circuit concepts.

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