Preface

As circuits and systems become more miniature and less power-consuming, we move towards a complete synthesis of systems and renewable power sources. This is an essential step towards fully autonomous, micro- and nano-scale smart systems that will become a part of the Internet of Things (IoT) trend. The area of engineering that develops autonomous energy sources, able to derive energy from environment, is called energy harvesting. It is a versatile, multidisciplinary and rapidly developing area that combines electronic engineering, materials science and physics with circuit design and system-level integration.

There are many energy sources available for harvesting in the environment. Perhaps, one of the most common examples of an energy harvester known to every reader is a solar cell. But this is not the only example though. In this book, we discuss vibration energy harvesting, a particular type of energy conversion from mechanical motion. Due to the ubiquitous nature of mechanical motion and vibrations, they seem as a very promising approach to supply microsystems with energy. Moreover, since we would like to focus on micro- and nano-systems, we will consider only electrostatic and electromagnetic energy conversion mechanisms, which are particularly suitable for implementation through microtechnologies and can be scaled down.

Since the idea of vibration energy harvesting has been introduced, it has become clear that there are certain challenges that cannot be addressed applying a conventional approach based on linear mechanical resonators. In particular, modern energy harvesters are required to be robust, to respond to a large range of external frequencies, and in some cases, to operate with noise-like vibrations. Often perceived as parasitic, nonlinearity in energy harvesting systems can address these particular challenges. As we shall show throughout the book, nonlinearity is inevitable and arises due to the nature of energy harvesters. Since energy harvesters are ‘mixed’ systems combining the electrical and the mechanical domains, the presence of electromechanical coupling causes nonlinearity that should not be neglected in analysis and, actually, can be utilised and improve the performance of a harvester.

This book covers a range of different topics related to nonlinearity in vibration energy harvesters. We start, however, with some fundamentals and explain what is microtechnology and how it is employed to build a harvester. We also present introductory discussions on oscillators and transducers for energy harvesters. With these fundamentals covered, we proceed and discuss each particular case of nonlinearity due to nonlinear mechanical resonators (nonlinearity in the mechanical domain) and conditioning circuits in electrostatic and piezoelectric harvesters (nonlinearity due to electromechanical coupling).

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