

Preface

Today's technology world is certainly evolving and is also bringing most innovative devices that have ever come to the market. One of those is called energy harvesting. Energy harvesting is the process of taking energy from external sources and converting it to electrical energy to supply any mobile device. Michael Faraday's law of induction found that moving a magnet through a loop of wire would create an electrical energy in terms of current. This principle can be one point of starting for energy harvesting. In the early twentieth century, a great scientist tried to pose the question to which we seek an answer yet. We all live in a solar system with an enormous amount of energy sent to the earth; adequate protection system (see the atmosphere) allows us to live and prevent the destruction of the planet under the powerful yield of energy from the sun. In addition to this, the earth is a living organism, or an accumulator and generator for various types of known and unknown energies. The question is legitimate: is it possible to be able to "catch" this enormous energy and make it available to users? Scientifically speaking, yes, it is possible; the thing is possible. A classic example is the photovoltaic cells that convert solar energy into an electrical signal (photovoltaic effect). This question was asked by Nikola Tesla. Currently, most of these electronic devices are powered by batteries. However, batteries have several disadvantages: they need to be replaced or recharge periodically and mostly they are not handy with their size and weight compared to a highly electronic technology. One possibility to overcome these power limitations is to extract energy from the environment to recharge a battery or even to directly power the electronic device. The environmental energy is naturally occurring in large and micro-scale; the technologies have been widely disseminated efficiently: solar energy is an example that although the overall efficiency remains remarkably low (around 30%), its usefulness is much appreciated, or almost. Fossil fuels are limited, expensive and, above all, not environmentally friendly as they induce a strong impact on land-based pollution. The photovoltaic system is a classical green system that converts solar energy to electric current to supply electronic devices. It needs improvements in terms of efficiency and new materials with the goal to be a system totally dependent in periods of minimum intensity of the sun. In this context, however, it is fundamental that the battery management system have a great capacity

and excellent long-term efficiency. How much energy is available around us? What kind of energy sources do we have? What is utility? They are some issues to which we will answer in this book through an engineering discussion with the basic and advanced concept about physics and electronic circuit. In addition to large-scale energy such as solar, there are variants of energy, which could be defined on a small scale to implement in low-power systems such as wearable and smartphone devices. Walking can also be used to produce energy by using an electromagnetic mechanism. The electronics and microelectronics are spreading steadily, and many companies provide day after day IC systems of energy harvesting for different types of energies such as electromagnetic. The purpose is always to harvest the energy dispersed in the environment for reusing it in other forms (electric current) to power other electronic devices or the same device in a way that we could define recycling energy loop. Collecting all these energies (heat, light, sound, vibration, movement) could have a significant impact concerning the economic and environmental factors, reducing costs and developing new sensor technologies. The main part of every electronic system is the battery, as in a computer or a smartphone, and thinking to recharge it by external source of energy in a harvesting automatic mode could be very impressive with zero-impact work process: a smartphone supplied by environmental energy without battery. Eliminating the battery is a long-term goal that in some systems such as photovoltaics is definitely an essential element in the design. The physical aspects that come into play in an energy-harvesting system can be described in terms of ability to store the energy, materials science, microelectronics for power management and systems engineering. All electronic systems such as computer and smartphones waste energy: why not charge your phone by using its electromagnetic waves that we know to be of greater intensity during calls and receiving data? Still, why not detect the energy that the universe sends to us, such as cosmic rays for the realisation of a low-power system to supply wearable systems. But it is interesting to note that there are other sources that have emerged from the action of man, as a consequence of industrial and technological development. These modern energy sources (or artificial) are directly related to energy harvesting; vibration or temperature gradients are produced by machines and engines. Even in the electromagnetic spectrum, we can collect the energy not only from the natural solar radiation but also by all the artificial radio sources which is acquiring a great importance with the development of web-based devices concerning IoT and IIoT. The technology behind energy harvesting is possible, thanks to a careful analysis and design of power management factors that have reduced the consumption of electronic systems. Although manufacturers struggle to reduce battery consumption, running out of power after just a few hours of use and having to be connected to a power supply to recharge are common problems that need a solution. The goal of the book is to focus on energy harvesting which is released into the environment in various types: electromagnetic, vibrational and heat. The most used sources are vibration, movement, all the mechanical energies and sound that can be captured and converted into electricity using piezoelectric materials. The heat can be captured and converted into electricity using thermal and pyroelectric materials. This book describes basic and advanced concepts of

energy harvesting in terms of physics and engineering and then proposes the design techniques to obtain power supplies for low-power systems. The first six chapters describe a special technology of energy harvesting including the different principles of transducer and related materials, power management, storage and design of system. In addition, design techniques with conditioning circuital solutions to efficiently manage a low-power system will be analysed. The final chapter describes various types of energy-harvesting applications and related market with a focus on future architectures.

Pescara, Italy
August 2016

Maurizio Di Paolo Emilio

Microelectronic Circuit Design for Energy Harvesting
Systems

Di Paolo Emilio, M.

2017, XXII, 169 p. 133 illus., 33 illus. in color., Hardcover

ISBN: 978-3-319-47586-8