

# Preface

## Preface to the Second Edition

The first edition of the book was one of the elements of my habilitation (a qualification above a Ph.D., which is a necessary step for obtaining the title of a professor in Poland and other European countries), and as a result it was subsequently very carefully reviewed by four reviewers. The habilitation was a success. Using the insightful comments from my reviewers, I have improved the current version and eliminated some typographic errors that were initially overlooked.

This book is based on the first edition of the book and besides some changes to the previous material, there are some new elements I include in the new edition. In particular, I add more MATLAB listings, which would further complement and enrich the text by providing worked examples of the solutions proposed in the book.

More figures are added and all the existing ones are revised and in color. My new solution for a shunt active power filter is also included in the new edition. All those changes are introduced in the Chapters from the first edition.

This book also includes a new Chapter considering selected problems of simulation of power electronic systems together with digital control circuits. These simulations are conducted using MATLAB and PSIM. In the case of the PSIM programs, the considered methods use C code for describing the digital control algorithm.

I have written this book in his endeavor to abide by the following maxim *nulla dies sine linea*  $\leftrightarrow$  *nie ma dnia bez kreski*  $\leftrightarrow$  *not a day without a line drawn* (Apelles, Greek painter, flourished 4th century bc). However, this is not always easily achieved.

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## Preface to the First Edition

Power electronics circuits are becoming increasingly important in the modern world due to the rapid progress in developments of microelectronics in areas such as microprocessors, digital signal processors, memory circuits, complementary metal-oxide-semiconductors, analog-to-digital converters, digital-to-analog converters and power semiconductors—especially metal-oxide-semiconductor field-effect transistors and insulated gate bipolar transistors.

Specifically, the development of power transistors has shifted the range of applications from a few amperes and hundreds of volts to several thousands of amperes and a few kilovolts, with a switching frequency measured in millions of hertz. Power electronics circuits are now used everywhere: in power systems, industry, telecommunications, transportation, commerce, etc. They even exist in such modern popular devices as digital cameras, mobile phones, and portable media players. Power electronics are also used in micropower circuits, especially in energy harvesting circuits.

In the early years of power electronics, in the sixties and seventies, analog control circuits were most commonly used, meaning that only the simplest control algorithms could be applied. Some years later, in the eighties and early nineties, hybrid control circuits were used, which consisted of both analog and digital components. In subsequent years there followed a slow transition to fully digitalized control systems, which are currently widely used and enabled the application of more complex digital signal processing algorithms.

In this book the author considers signal processing, starting from analog signal acquisition, through its conversion to digital form, methods of its filtration and separation, and ending with pulse control of output power transistors. The author has focused on two applications for the considered methods of digital signal processing: an active power filter and a digital class-D power amplifier.

Both applications require precise digital control circuits with very high dynamic range of control signals. Therefore, in the author's opinion these applications will provide very good illustrations for the considered methods. In this book the author's original solutions for both applications are presented. In the author's opinion the adopted solutions can also be extended to other power electronics devices.

The discussion of the first application, APF, starts with the analysis of first harmonic detectors based on: IIR filter, wave digital filters, sliding DFT and sliding Goertzel, moving DFT. Following that, author's implementation of classical control circuits based on  $p - q$  algorithm is presented. Next, the dynamics of APF is considered. Dynamic distortion of APF makes it impossible to fully compensate line harmonics. In some cases, the line current *THD* ratio for systems with APF compensation can reach a value of a dozen or so percent. Therefore the author has dealt with this problem by proposing APF models suitable for analysis and simulation of this phenomenon. For predictable line current changes, it is possible to develop a predictable control algorithm to eliminate APF dynamics compensation

errors. In the following sections the author's modification using a predictive circuit to eliminate dynamic compensation errors is described. In this book control circuits with filter banks which allow the selection of compensated harmonics are described. The considered filter banks are based on sliding DFT, sliding Goertzel, moving DFT and  $p - q$  algorithm.

For unpredictable line current changes the author has developed a multirate APF. The presented multirate APF has a fast response for sudden changes in the load current. So, using multirate APF, it is possible to decrease the *THD* ratio of line current even for unpredictable loads.

The second application is a digital class-D amplifier. Both APFs and the amplifiers are especially demanding in terms of the dynamics of processed signals. However, in the case of a class-D amplifier, the dynamics reach 120 dB, which results in high requirements for the type of algorithm used and its digital realization. The author has proposed a modulator with a noise shaping circuit for a class-D amplifier. Interpolators are also considered that allow for the increasing of the sampling frequency whilst maintaining a substantial separation of signal from noise. The author also presents an original analog power supply voltage fluctuation compensation circuit for the class-D amplifier. The class-D amplifier with digital click modulation is given special consideration too. Finally, two-way and three-way loudspeaker systems, designed by the author, are presented, where the signal from input to output is digitally processed.

The great majority of the presented methods and circuits is the original work of the author. Listings from MATLAB or in C language are attached to some of the considered algorithms to make the application of the algorithms easier. The presented methods and circuits can be successfully applied to the whole range of power electronics circuits.

The issues concerning digital signal processing are relatively widely described in the literature. However, in the author's opinion, there are very few publications combining digital signal processing and power electronics, due to the fact that these two areas of knowledge have been developed independently over the years. The author hopes that this book will, to some extent, bridge the gap between digital signal processing and power electronics. This book may be useful for scientists and engineers who implement control circuits, as well as for students of electrical engineering courses. It may also be of some value to those who create new topologies and new power electronics circuits, giving them some insights into possible control algorithms.

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