Foreword

It is hard to underestimate the impact that electronic systems have on society. My first portable radio was proudly marked “7 transistors.” Today, the electronic system in my pocket has over 2 trillion (2e12) transistors. There are 20 times more transistors in my smartphone than there are stars in the Milky Way galaxy. This unprecedented scale is enabled by the exponential self-fulfilling promise of Moore’s law. For over 50 years, the component integration density has been doubling every 18–24 months, while per-device cost went down at the same rate. In all of history, no other industrial law has been as reliable, and no other law has been as influential. Moore’s law has fueled the PC revolution in the 1980s, the Internet in the 1990s, the social media in the 2000s, the smartphone, and now the machine learning revolution. New electronic systems extend our senses, helping us see, helping us navigate, and helping us drive safely. The impact reaches beyond the gadgets: Electronic systems affect the way everybody works and lives. It is even fueling political revolutions, for better or for worse….

It is easily overlooked that Moore’s law implies that the human designers of electronic systems need to improve their productivity at the same exponential rate. Even a large company like Apple could not afford to double the size of their design team every two years to keep up with design scale. The A10 chip in the iPhone 7 is estimated to have 10× the number of components as the A4 chip in the iPhone 4 just five years earlier. The size of the design team, however, remained roughly the same.

It is no small achievement that electronic systems of this scale can be successfully designed, engineered, and mass-produced. This book addresses the engineering fundamentals behind the design process of effective and reliable electronic systems. Both students and professionals alike will appreciate the contents: The first because it sets up the fundamentals of the entire design process in detail, and the latter because the book brings together state-of-the-art design skills from the extensive experience of the authors.

The first chapters of the book address the architecture and fundamental structure of the design process of electronic systems. That includes the engineering decisions on breaking up the design into more manageable partitions. This must be done in a way that makes assembly straightforward and reliable. It must also be done while taking into account the limitations of tools, physics, regulatory rules, and people.

The main thrust of this book is addressing ways to "tame" the physical effects and control the unwanted side effects of the large-scale integration. The objective is to make the system reliable in production and use, and to make it resilient against external influences. The authors lay down thorough in-depth description of the theory and practice of reliability engineering. After all, it is only as strong as the weakest link.

A significant portion of this book addresses the heat that is dissipated in the electronic system. This is a point where the steady progression of Moore's law poses a true challenge, as the transistor density continues to increase exponentially while the per-transistor power does not decrease at the same rate. To keep the device temperature under control, either the heat needs to be avoided or the heat transfer rate needs to be maximized. The authors present the fundamentals on assessing and optimizing heat flows of electronic systems.

There have been several occasions where products malfunction because of electromagnetic interference. To avoid such design errors, this book provides an excellent description on reducing such unwanted coupling of the system and the environment. The clear set of guidelines and design recommendations is provided to ruggedize the electronic system from the start.

Once an afterthought, minimizing the environmental impact of electronic systems is becoming a major design criterion. There are already billions of electronic systems surrounding us, most of which have a relatively short life span. At the same time, the highly compact and integrated nature of electronic systems makes them harder to open and disassemble. Therefore, even small design improvements matter. An in-depths guide to addressing all environmental aspects during the full design cycle is presented by the authors.

This unique book provides fundamental, complete, and indispensable information regarding the design of electronic systems. This topic has not been addressed as complete and thorough anywhere before. Since the authors are world-renown experts, it is a foundational reference for today's design professionals, as well as for the next generation of engineering students.

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Preface

> If you have an extreme passion for producing great products, it pushes you to be integrated… It takes a lot of hard work to make something simple, to truly understand the underlying challenges and come up with elegant solutions.
>
> Steve Jobs

We are rarely aware, in our daily use of smartphones, notebooks, etc., that the development of mobile electronic devices started only a few decades ago. After the discovery of the transistor in 1948, the first integrated circuit was built in 1960, followed by the microprocessor in 1971. Then in 1973, Motorola developed the first prototype mobile phone, in 1976, Apple Computer introduced the *Apple I,* and IBM introduced the *IBM PC* in 1981. The popularity in the late 1990s of cell phones and increasingly powerful laptop computers foreshadowed the *iPhones* and *iPads* that became ubiquitous at the turn of the century. We have truly become a society immersed in mobile electronic devices.

The packaging density, i.e., the number of components per unit volume, has increased consistently throughout this period and shows little indication of slowing down. The resulting amount of heat to be dissipated increased as well, putting the spotlight on heat transfer issues. It further became obvious that the reliability, i.e., the function and durability of electronic components, depends greatly on temperature. Another problem identified was the undesirable influence of switching functions, caused by unwanted signals inside and outside packages. These issues came under the heading of *electronic systems design*, which quickly became an important interdisciplinary subdiscipline of electrical engineering.

Since the first appearance of mobile electronic devices, such as the transistor radio in 1954, components have undergone massive development and miniaturization; integrated circuits have reached unheard of complexity levels, and new packaging methods coupled with computer-aided design (CAD) have revolutionized the design of electronic systems. More recently, recycling and environmental requirements were also added to the mix. It is amazing to realize that every smartphone today has more computing power than the on-board computer in

Apollo 11, which transported the first humans to another astronomical object back in 1969.

This book addresses this enormous scientific progress and offers a review of the current state of the art in the development of electronic systems. It is the result of the extensive experience of its two authors in industry, academic research, and teaching in electronic systems design. Its aim is to support the reader with the development and fabrication of modern electronic devices, taking all relevant aspects into consideration with a clear presentation of the underlying technical and scientific principles. The book elucidates a broad range of techniques that have helped keep German engineering at the cutting edge for several decades and will continue to do so for decades to come.

A book of such considerable scope can never be accomplished by one individual. The authors wish to express their warm appreciation and thanks to all who helped produce this publication. We would like to mention in particular Martin Forrestal for his key role in writing the English version of the book. Our warm thanks go to Dr. Mike Alexander who has greatly assisted in the preparation of the English text. We also wish to sincerely thank the following for their support with subsections of the manuscript: Dr. Alfred Kamusella (Sect. 2.6), Dr. Helmut Löbl (Chap. 5), Prof. Stefan Dickmann and Dr. Ralf Jacobs (Chap. 6), Prof. Karl-Heinz Gonschorek (Sect. 6.6), Prof. Günter Röhrs (Chap. 7), Steve Bigalke (Appendices 8.1 and 8.2), and Dr. Frank Reifegerste (Appendices 8.4 and 8.5). Thanks are also due to Nicole Lowary and Charles B. Glaser of Springer for being very supportive and going beyond their call of duty to help out with our requests.

Rapid progress will continue to be made in electronic systems design in the years to come, perhaps by some of the readers of this humble book. The authors are always grateful for any comments or ideas for the future development of the book, and wish you good luck in your careers.

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