国外电子信息精品著作(影印版)

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Embedded System Design

Peter Marwedel

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www.sciencep.com

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北京

图字：01-2006-7421

内 容 简 介

本书针对近年来IT行业对嵌入式系统的需求，从总体上的介绍了嵌入式系统的设计，阐明了嵌入式系统设计中的一些主要方面之间的关系。另外，从作者的网站还可以下载相关的幻灯片、练习题和其他资料，从而使读者能够充分利用本书的资源。因此，本书既可作为相关领域专家的重要参考资料，又可作为当前嵌入式系统教学中所需的一本实用的教材；既可以作为嵌入式系统的入门参考，也可以作为研究人员的参考书，对当前的课程教学能起到很好的补充作用。

图书在版编目(CIP)数据

嵌入式系统设计= Embedded System Design：英文/（德）马威德尔（Marwedel，P.）编著. —影印版. —北京：科学出版社，2007.1
（国外电子信息精品著作）

ISBN 978-7-03-018247-0

Ⅰ.嵌… Ⅱ.马… Ⅲ.嵌入-系统设计-英文 Ⅳ.TP360.21

中国版本图书馆CIP数据核字(2006)第149511号

责任编辑：余 丁/责任印制：安春生/封面设计：陈 敬

科学出版社出版
北京东黄城根北街16号
邮政编码：100717
http://www.sciencep.com

天时彩色印刷有限公司印刷

科学出版社发行 各地新华书店经销

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2007年1月第 一 版 开本：B5(720×1000)
2007年1月第一次印刷 印张：16 1/4
印数：1—3 000 字数：396 000

定价：38.00元

（如有印装质量问题，我社负责调换〈双青〉）

《国外电子信息精品著作》序

20世纪90年代以来，信息科学技术成为世界经济的中坚力量。随着经济全球化的进一步发展，以微电子、计算机、通信和网络技术为代表的信息技术，成为人类社会进步过程中发展最快、渗透性最强、应用面最广的关键技术。信息技术的发展带动了微电子、计算机、通信、网络、超导等产业的发展，促进了生命科学、新材料、能源、航空航天等高新技术产业的成长。信息产业的发展水平不仅是社会物质生产、文化进步的基本要素和必备条件，也是衡量一个国家的综合国力、国际竞争力和发展水平的重要标志。在中国，信息产业在国民经济发展中占有举足轻重的地位，成为国民经济重要支柱产业。然而，中国的信息科学支持技术发展的力度不够，信息技术还处于比较落后的水平，因此，快速发展信息科学技术成为我国迫在眉睫的大事。

要使我国的信息技术更好地发展起来，需要科学工作者和工程技术人员付出艰辛的努力。此外，我们要从客观上为科学工作者和工程技术人员创造更有利于发展的环境，加强对信息技术的支持与投资力度，其中也包括与信息技术相关的图书出版工作。

从出版的角度考虑，除了较好较快地出版具有自主知识产权的成果外，引进国外的优秀出版物是大有裨益的。洋为中用，将国外的优秀著作引进到国内，促进最新的科技成就迅速转化为我们自己的智力成果，无疑是值得高度重视的。科学出版社引进一批国外知名出版社的优秀著作，使我国从事信息技术的广大科学工作者和工程技术人员能以较低的价格购买，对于推动我国信息技术领域的科研与教学是十分有益的事。

此次科学出版社在广泛征求专家意见的基础上，经过反复论证、仔细遴选，共引进了接近30本外版书，大体上可以分为两类，第一类是基础理论著作，第二类是工程应用方面的著作。所有的著作都涉及信息领域的最新成果，大多数是2005年后出版的，力求“层次高、内

容新、参考性强”。在内容和形式上都体现了科学出版社一贯奉行的严谨作风。

当然，这批书只能涵盖信息科学技术的一部分，所以这项工作还应该继续下去。对于一些读者面较广、观点新颖、国内缺乏的好书还应该翻译成中文出版，这有利于知识更好更快地传播。同时，我也希望广大读者提出好的建议，以改进和完善丛书的出版工作。

总之，我对科学出版社引进外版书这一举措表示热烈的支持，并盼望这一工作取得更大的成绩。

中国科学院院士
中国工程院院士
2006 年 12 月

Preface

Importance of embedded systems

Embedded systems can be defined as information processing systems embedded into enclosing products such as cars, telecommunication or fabrication equipment. Such systems come with a large number of common characteristics, including real-time constraints, and dependability as well as efficiency requirements. Embedded system technology is essential for providing ubiquitous information, one of the key goals of modern information technology (IT).

Following the success of IT for office and workflow applications, embedded systems are considered to be **the** most important application area of information technology during the coming years. Due to this expectation, the term **post-PC era** was coined. This term denotes the fact that in the future, standard-PCs will be a less dominant kind of hardware. Processors and software will be used in much smaller systems and will in many cases even be invisible (this led to the term **the disappearing computer**). It is obvious that many technical products have to be technologically advanced to find customers' interest. Cars, cameras, TV sets, mobile phones etc. can hardly be sold any more unless they come with smart software. The number of processors in embedded systems already exceeds the number of processors in PCs, and this trend is expected to continue. According to forecasts, the size of embedded software will also increase at a large rate. Another kind of Moore's law was predicted: *For many products in the area of consumer electronics the amount of code is doubling every two years* [Vaandrager, 1998].

This importance of embedded systems is so far not well reflected in many of the current curricula. This book is intended as an aid for changing this situation. It provides the material for a first course on embedded systems, but can also be used by non-student readers.

Audience for this book

This book intended for the following audience:

- Computer science, computer engineering and electrical engineering students who would like to specialize in embedded systems. The book should be appropriate for third year students who do have a basic knowledge of computer hardware and software. This book is intended to pave the way for more advanced topics that should be covered in a follow-up course.
- Engineers who have so far worked on systems hardware and who have to move more towards software of embedded systems. This book should provide enough background to understand the relevant technical publications.
- Professors designing a new curriculum for embedded systems.

Curriculum integration of embedded systems

The book assumes a basic understanding in the following areas (see fig. 0.1):

- electrical networks at the high-school level (e.g. Kirchhoff's laws),
- operational amplifiers (optional),
- computer hardware, for example at the level of the introductory book by J.L. Hennessy and D.A. Patterson [Hennessy and Patterson, 1995],
- fundamental digital circuits such as gates and registers,
- computer programming,
- finite state machines,
- fundamental mathematical concepts such as tuples, integrals, and linear equations,
- algorithms (graph algorithms and optimization algorithms such as branch and bound),
- the concept of NP-completeness.

A key goal of this book is to provide an overview of embedded system design and to relate the most important topics in embedded system design to each other. It should help to motivate students and teachers to look at more details. While the book covers a number of topics in detail, others are covered only briefly. These brief sections have been included in order to put a number of

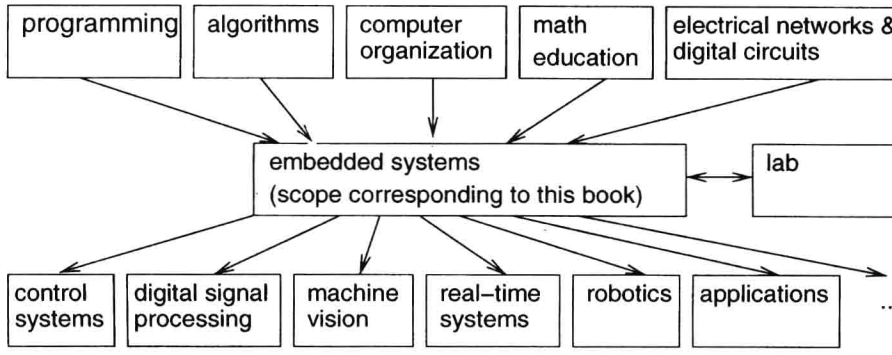

Figure 0.1. Positioning of the topics of this book

related issues into perspective. Furthermore, this approach allows lecturers to have appropriate links in the book for adding complementary material of their choice. The book should be complemented by follow-up courses providing a more specialized knowledge in some of the following areas:

- digital signal processing,
- robotics,
- machine vision,
- sensors and actors,
- real-time systems, real-time operating systems, and scheduling,
- control systems,
- specification languages for embedded systems,
- computer-aided design tools for application-specific hardware,
- formal verification of hardware systems,
- testing of hardware and software systems,
- performance evaluation of computer systems,
- low-power design techniques,
- security and dependability of computer systems,
- ubiquitous computing,
- application areas such as telecom, automotive, medical equipment, and smart homes,

- impact of embedded systems.

A course using this book should be complemented by an exiting lab, using, for example, small robots, such as Lego Mindstorm^{TM} or similar robots. Another option is to let students gain some practical experience with StateCharts-based tools.

Additional information related to the book can be obtained from the following web page:

http://ls12-www.cs.uni-dortmund.de/~marwedel/kluwer-es-book.

This page includes links to slides, exercises, hints for running labs, references to selected recent publications and error corrections. Readers who discover errors or who would like to make comments on how to improve the book should send an e-mail to peter.marwedel@udo.edu.

Assignments could also use the information in complementary books [Ganssle, 1992], [Ball, 1996], [Ball, 1998], [Barr, 1999], [Ganssle, 2000], [Wolf, 2001], [Buttazzo, 2002].

Please enjoy reading the book!

Dortmund (Germany), September 2003

P. Marwedel

Welcome to the current updated version of this book! The merger of Kluwer and Springer publishers makes it possible to publish this version of the book less than two years after the initial 2003 version. In the current version, all typos and errors found in the original version have been corrected. Moreover, all Internet references have been checked and updated. Apart from these changes, the content of the book has not been modified. A list of the errors corrected is available at the web page listed above.

Please enjoy reading this updated book.

Dortmund (Germany), August 2005

P. Marwedel

Acknowledgments

My PhD students, in particular Lars Wehmeyer, did an excellent job in proofreading a preliminary version of this book. Also, the students attending my course "Introduction to Embedded Systems" of the summer of 2003 (in particular Lars Bensmann) provided valuable help. In addition, the following colleagues and students gave comments or hints which were incorporated into this book: W. Müller, F. Rammig (U. Paderborn), W. Rosenstiel (U. Tübingen), R. Dömer (UC Irvine), and W. Kluge (U. Kiel). Material from the following persons was used to prepare this book: G. C. Buttazzo, D. Gajski, R. Gupta, J. P. Hayes, H. Kopetz, R. Leupers, R. Niemann, W. Rosenstiel, and H. Takada. Corrections to the 2003 hardcopy version of the book were proposed by David Hec, Thomas Wiederkehr, and Thorsten Wilmer. Of course, the author is responsible for all remaining errors and mistakes.

Acknowledgments also go to all those who have patiently accepted the author's additional workload during the writing of this book and his resulting reduced availability for professional as well as personal partners.

Finally, it should be mentioned that Kluwer Academic Publishers (now Springer) has supported the publication of the book from its initial conception. Their support has been stimulating during the work on this book.

Contents

Chapter 1

INTRODUCTION

1.1 Terms and scope

Until the late eighties, information processing was associated with large mainframe computers and huge tape drives. During the nineties, this shifted towards information processing being associated with personal computers, PCs. The trend towards miniaturization continues and the majority of information processing devices will be small portable computers integrated into larger products. Their presence in these larger products, such as telecommunication equipment will be less obvious than for the PC. Hence, the new trend has also been called the **disappearing computer**. However, with this new trend, the computer will actually not disappear, it will be everywhere. This new type of information technology applications has also been called **ubiquitous computing** [Weiser, 2003], **pervasive computing** [Hansmann, 2001], [Burkhardt, 2001], and **ambient intelligence** [Koninklijke Philips Electronics N.V., 2003], [Marzano and Aarts, 2003]. These three terms focus on only slightly different aspects of future information technology. Ubiquitous computing focuses on the long term goal of providing "information anytime, anywhere", whereas pervasive computing focuses a somewhat more on practical aspects and the exploitation of already available technology. For ambient intelligence, there is some emphasis on communication technology in future homes and smart buildings. Embedded systems are one of the origins of these three areas and they provide a major part of the necessary technology. **Embedded systems are information processing systems that are embedded into a larger product** and that are normally not directly visible to the user. Examples of embedded systems include information processing systems in telecommunication equipment, in transportation systems, in fabrication equipment and in consumer electronics. Common characteristics of these systems are the following:

- Frequently, embedded systems are connected to the physical environment through **sensors** collecting information about that environment and **actuators**[1] controlling that environment.

- Embedded systems have to be **dependable**.

  Many embedded systems are safety-critical and therefore have to be dependable. Nuclear power plants are an example of extremely safety-critical systems that are at least partially controlled by software. Dependability is, however, also important in other systems, such as cars, trains, airplanes etc. A key reason for being safety-critical is that these systems are directly connected to the environment and have an immediate impact on the environment.

  Dependability encompasses the following aspects of a system:

  1 **Reliability:** Reliability is the probability that a system will not fail.

  2 **Maintainability:** Maintainability is the probability that a failing system can be repaired within a certain time-frame.

  3 **Availability:** Availability is the probability that the system is available. Both the reliability and the maintainability must be high in order to achieve a high availability.

  4 **Safety:** This term describes the property that a failing system will not cause any harm.

  5 **Security:** This term describes the property that confidential data remains confidential and that authentic communication is guaranteed.

- Embedded systems have to be **efficient**. The following metrics can be used for evaluating the efficiency of embedded systems:

  1 **Energy:** Many embedded systems are mobile systems obtaining their energy through batteries. According to forecasts [SEMATECH, 2003], battery technology will improve only at a very slow rate. However, computational requirements are increasing at a rapid rate (especially for multimedia applications) and customers are expecting long run-times from their batteries. Therefore, the available electrical energy must be used very efficiently.

  2 **Code-size:** All the code to be run on an embedded system has to be stored with the system. Typically, there are no hard discs on which code can be stored. Dynamically adding additional code is still an exception and limited to cases such as Java-phones and set-top boxes.

[1] In this context, actuators are devices converting numerical values into physical effects.