

国外电子与通信教材系列

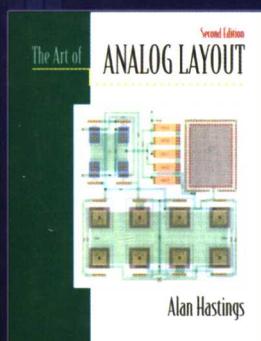
英文版

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模拟电路版图的艺术

(第二版)

The Art of Analog Layout
Second Edition



[美] Alan Hastings 著



电子工业出版社

Publishing House of Electronics Industry
<http://www.phei.com.cn>

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北京 · BEIJING

内 容 简 介

作者Alan Hastings具有渊博的集成电路版图设计知识和丰富的实践经验。本书以实用和权威性的观点全面论述了模拟集成电路版图设计中所涉及的各种问题及目前的最新研究成果。书中介绍了半导体器件物理与工艺、失效机理等内容；基于模拟集成电路设计所采用的3种基本工艺：标准双极工艺、CMOS硅栅工艺和BiCMOS工艺，重点探讨了无源器件的设计与匹配性问题，二极管设计，双极型晶体管和场效应晶体管的设计与应用，以及某些专门领域的内容，包括器件合并、保护环、焊盘制作、单层连接、ESD结构等；最后介绍了有关芯片版图的布局布线知识。本书可作为相关专业高年级本科生和研究生教材，对于专业版图设计人员也是一本极具价值的参考书。

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序

2001年7月间,电子工业出版社的领导同志邀请各高校十几位通信领域方面的老师,商量引进国外教材问题。与会同志对出版社提出的计划十分赞同,大家认为,这对我国通信事业、特别是对高等院校通信学科的教学工作会很有好处。

教材建设是高校教学建设的主要内容之一。编写、出版一本好的教材,意味着开设了一门好的课程,甚至可能预示着一个崭新学科的诞生。20世纪40年代MIT林肯实验室出版的一套28本雷达丛书,对近代电子学科、特别是对雷达技术的推动作用,就是一个很好的例子。

我国领导部门对教材建设一直非常重视。20世纪80年代,在原教委教材编审委员会的领导下,汇集了高等院校几百位富有教学经验的专家,编写、出版了一大批教材;很多院校还根据学校的特点和需要,陆续编写了大量的讲义和参考书。这些教材对高校的教学工作发挥了极好的作用。近年来,随着教学改革不断深入和科学技术的飞速进步,有的教材内容已比较陈旧、落后,难以适应教学的要求,特别是在电子学和通信技术发展神速、可以讲是日新月异的今天,如何适应这种情况,更是一个必须认真考虑的问题。解决这个问题,除了依靠高校的老教师和专家撰写新的符合要求的教科书外,引进和出版一些国外优秀电子与通信教材,尤其是有选择地引进一批英文原版教材,是会有好处的。

一年多来,电子工业出版社为此做了很多工作。他们成立了一个“国外电子与通信教材系列”项目组,选派了富有经验的业务骨干负责有关工作,收集了230余种通信教材和参考书的详细资料,调来了100余种原版教材样书,依靠由20余位专家组成的出版委员会,从中精选了40多种,内容丰富,覆盖了电路理论与应用、信号与系统、数字信号处理、微电子、通信系统、电磁场与微波等方面,既可作为通信专业本科生和研究生的教学用书,也可作为有关专业人员的参考材料。此外,这批教材,有的翻译为中文,还有部分教材直接影印出版,以供教师用英语直接授课。希望这些教材的引进和出版对高校通信教学和教材改革能起一定作用。

在这里,我还要感谢参加工作的各位教授、专家、老师与参加翻译、编辑和出版的同志们。各位专家认真负责、严谨细致、不辞辛劳、不怕琐碎和精益求精的态度,充分体现了中国教育工作者和出版工作者的良好美德。

随着我国经济建设的发展和科学技术的不断进步,对高校教学工作会不断提出新的要求和希望。我想,无论如何,要做好引进国外教材的工作,一定要联系我国的实际。教材和学术专著不同,既要注意科学性、学术性,也要重视可读性,要深入浅出,便于读者自学;引进的教材要适应高校教学改革的需要,针对目前一些教材内容较为陈旧的问题,有目的地引进一些先进的和正在发展中的交叉学科的参考书;要与国内出版的教材相配套,安排好出版英文原版教材和翻译教材的比例。我们努力使这套教材能尽量满足上述要求,希望它们能放在学生们的课桌上,发挥一定的作用。

最后,预祝“国外电子与通信教材系列”项目取得成功,为我国电子与通信教学和通信产业的发展培土施肥。也恳切希望读者能对这些书籍的不足之处、特别是翻译中存在的问题,提出意见和建议,以便再版时更正。



中国工程院院士、清华大学教授
“国外电子与通信教材系列”出版委员会主任

出版说明

进入21世纪以来,我国信息产业在生产和科研方面都大大加快了发展速度,并已成为国民经济发展的支柱产业之一。但是,与世界上其他信息产业发达的国家相比,我国在技术开发、教育培训等方面都还存在着较大的差距。特别是在加入WTO后的今天,我国信息产业面临着国外竞争对手的严峻挑战。

作为我国信息产业的专业科技出版社,我们始终关注着全球电子信息技术的发展方向,始终把引进国外优秀电子与通信信息技术教材和专业书籍放在我们工作的重要位置上。在2000年至2001年间,我社先后从世界著名出版公司引进出版了40余种教材,形成了一套“国外计算机科学教材系列”,在全国高校以及科研部门中受到了欢迎和好评,得到了计算机领域的广大教师与科研工作者的充分肯定。

引进和出版一些国外优秀电子与通信教材,尤其是有选择地引进一批英文原版教材,将有助于我国信息产业培养具有国际竞争能力的技术人才,也将有助于我国国内在电子与通信教学工作中掌握和跟踪国际发展水平。根据国内信息产业的现状、教育部《关于“十五”期间普通高等教育教材建设与改革的意见》的指示精神以及高等院校老师们反映的各种意见,我们决定引进“国外电子与通信教材系列”,并随后开展了大量准备工作。此次引进的国外电子与通信教材均来自国际著名出版商,其中影印教材约占一半。教材内容涉及的学科方向包括电路理论与应用、信号与系统、数字信号处理、微电子、通信系统、电磁场与微波等,其中既有本科专业课程教材,也有研究生课程教材,以适应不同院系、不同专业、不同层次的师生对教材的需求,广大师生可自由选择和自由组合使用。我们还将与国外出版商一起,陆续推出一些教材的教学支持资料,为授课教师提供帮助。

此外,“国外电子与通信教材系列”的引进和出版工作得到了教育部高等教育司的大力支持和帮助,其中的部分引进教材已通过“教育部高等学校电子信息科学与工程类专业教学指导委员会”的审核,并得到教育部高等教育司的批准,纳入了“教育部高等教育司推荐——国外优秀信息科学与技术系列教学用书”。

为作好该系列教材的翻译工作,我们聘请了清华大学、北京大学、北京邮电大学、南京邮电大学、东南大学、西安交通大学、天津大学、西安电子科技大学、电子科技大学、中山大学、哈尔滨工业大学、西南交通大学等著名高校的教授和骨干教师参与教材的翻译和审校工作。许多教授在国内电子与通信专业领域享有较高的声望,具有丰富的教学经验,他们的渊博学识从根本上保证了教材的翻译质量和专业学术方面的严格与准确。我们在此对他们的辛勤工作与贡献表示衷心的感谢。此外,对于编辑的选择,我们达到了专业对口;对于从英文原书中发现的错误,我们通过与作者联络、从网上下载勘误表等方式,逐一进行了修订;同时,我们对审校、排版、印制质量进行了严格把关。

今后,我们将进一步加强同各高校教师的密切关系,努力引进更多的国外优秀教材和教学参考书,为我国电子与通信教材达到世界先进水平而努力。由于我们对国内外电子与通信教育的发展仍存在一些认识上的不足,在选题、翻译、出版等方面的工作中还有许多需要改进的地方,恳请广大师生和读者提出批评及建议。

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Preface to the Second Edition

I originally wrote *The Art of Analog Layout* as a companion volume to a series of lectures. Many people encouraged me to publish it. At first I was reluctant to do so, for I thought that it would find a rather limited audience. Publication has proven my concerns quite unfounded. To my astonishment, *The Art of Analog Layout* has even been translated into Chinese!

The passage of several years has alerted me to the limitations of the first edition and prompted an extensive revision. Every chapter has been examined and corrected. Many new passages have been added, along with some 50 new illustrations to accompany them. New topics introduced in the second edition include the following:

- Advanced metallization systems
- Dielectric isolation
- Failure mechanisms of MOS transistors
- Integrated inductors
- MOS safe operating area
- Nonvolatile memory

In preparing this edition, I have drawn extensively upon the experience and wisdom of my colleagues at Texas Instruments. I have also made constant reference to the resources available upon the IEEE Xplore website, most particularly those contained in the *IEEE Journal of Electron Devices*. I thank all the many people who have contributed to my own understanding or who have corrected my many mistakes. A work of this length and magnitude will never prove perfect, but the second edition greatly improves upon the first.

ALAN HASTINGS

Preface to the First Edition

An integrated circuit reveals its true appearance only under high magnification. The intricate tangle of microscopic wires covering its surface and the equally intricate patterns of doped silicon beneath it, all follow a set of blueprints called a *layout*. The process of constructing layouts for analog and mixed-signal integrated circuits has stubbornly defied all attempts at automation. The shape and placement of every polygon requires a thorough understanding of the principles of device physics, semiconductor fabrication, and circuit theory. Despite 30 years of research, much remains uncertain. What information there is lies buried in obscure journal articles and unpublished manuscripts. This textbook assembles that information between a single set of covers. While primarily intended for use by practicing layout designers, it should also prove valuable to circuit designers who desire a better understanding of the relationship between circuits and layouts.

The text has been written for a broad audience, some of whom have had only limited exposure to higher mathematics and solid-state physics. The amount of mathematics has been kept to an absolute minimum, and care has been taken to identify all variables and to use the most accessible units. The reader need only have a familiarity with basic algebra and elementary electronics. Many of the exercises assume that the reader also has access to layout editing software; but those who lack such resources can complete many of the exercises with pencil and paper.

The text consists of 14 chapters and five appendices. The first two chapters provide an overview of device physics and semiconductor processing. These chapters avoid mathematical derivations and instead emphasize simple verbal explanations and visual models. The third chapter presents three archetypal processes: standard bipolar, silicon-gate CMOS, and analog BiCMOS. The presentation focuses upon development of cross sections and the correlation of these cross sections to conventional layout views of sample devices. The fourth chapter covers common failure mechanisms and emphasizes the role of layout in determining reliability. Chapters 5 and 6 cover the layout of resistors and capacitors. Chapter 7 presents the principles of matching, using resistors and capacitors as examples. Chapters 8 through 10 cover the layout of bipolar devices, while Chapters 11 and 12 cover the layout and matching of field-effect transistors. Chapters 13 and 14 cover a variety of advanced topics, including device mergers, guard rings, ESD protection structures, and floorplanning. The appendices include a list of acronyms, a discussion of Miller indices, sample layout rules for use in working the exercises, and the derivation of formulas used in the text.

ALAN HASTINGS

Acknowledgments

The information contained in this text has been gathered through the hard work of many scientists, engineers, and technicians, the vast majority of whom must remain unacknowledged because their work has not been published. I have included references to as many fundamental discoveries and principles as I could, but in many cases I have been unable to determine original sources.

I thank my colleagues at Texas Instruments for numerous suggestions. I am especially grateful to Ken Bell, Walter Bucksch, Taylor Efland, Lou Hutter, Clif Jones, Alec Morton, Jeff Smith, Fred Trafton, and Joe Trogolo, all of whom have provided important information for this text. I am also grateful for the encouragement of Bob Borden, Nicolas Salamina, and Ming Chiang, without which this book would never have been written.

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