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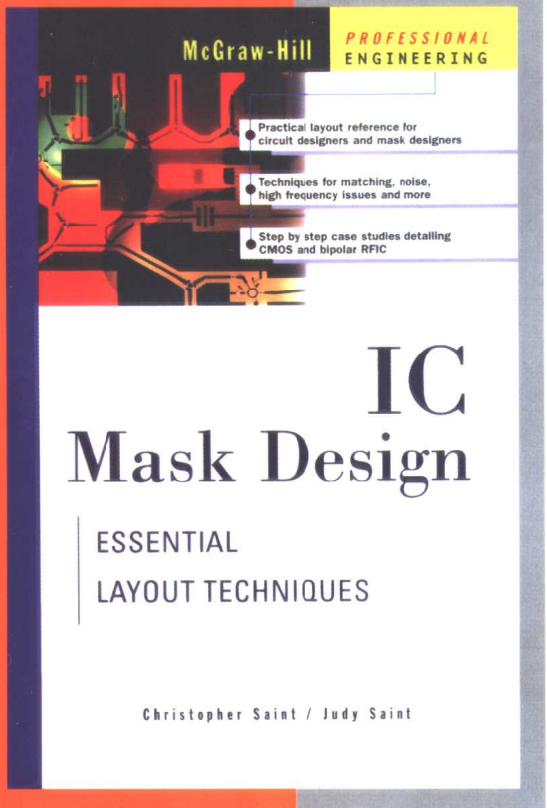
Christopher Saint, Judy Saint

集成电路版图设计



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集成电路版图设计

IC Mask Design
Essential Layout Techniques

Christopher Saint
Judy Saint

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出 版 前 言

微电子技术是信息科学技术的核心技术之一，微电子产业是当代高新技术产业群的核心和维护国家主权、保障国家安全的战略性产业。我国在《信息产业“十五”计划纲要》中明确提出：坚持自主发展，增强创新能力和核心竞争力，掌握以集成电路和软件技术为重点的信息产业的核心技术，提高具有自主知识产权产品的比重。发展集成电路技术的关键之一是培养具有国际竞争力的专业人才。

微电子技术发展迅速，内容更新快，而我国微电子专业图书数量少，且内容和体系不能反映科技发展的水平，不能满足培养人才的需求，为此，我们系统挑选了一批国外经典教材和前沿著作，组织分批出版。图书选择的几个基本原则是：在本领域内广泛采用，有很大影响力；内容反映科技的最新发展，所述内容是本领域的研究热点；编写和体系与国内现有图书差别较大，能对我国微电子教育改革有所启示。本套丛书还侧重于微电子技术的实用性，选取了一批集成电路设计方面的工程技术用书，使读者能方便地应用于实践。本套丛书不仅能作为相关课程的教科书和教学参考书，也可作为工程技术人员的自学读物。

我们真诚地希望，这套丛书能对国内高校师生、工程技术人员以及科研人员的学习和工作有所帮助，对推动我国集成电路的发展有所促进。也衷心期望着广大读者对我们一如既往的关怀和支持，鼓励我们出版更多、更好的图书。

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IC Mask Design

Essential Layout Techniques

影 印 版 序

集成电路的出现与飞速发展是科技进步的一大奇迹，它不仅给人类的生产建设和科学研究带来了巨大成功而且也彻底改变了人类文明和人们日常生活的面目，可以毫不夸张地说，现今每个人生活的方方面面或多或少都和集成电路密切相关。

集成电路是电子电路，但它又不同于一般意义上的电子电路，它把成千上万的电子元件包括晶体管、电阻、电容甚至电感集成在微小的芯片上，正是这种奇妙的设计和制造方式使它为人类社会的进步创造了空前的奇迹，而使这种奇迹变为现实的正是集成电路版图设计。

集成电路的版图与集成电路的概念是一起诞生的，可以说没有版图就没有集成电路。集成电路版图设计是实现集成电路制造所必不可少的设计环节，它不仅关系到集成电路的功能是否正确，而且也会极大程度地影响集成电路的性能、成本与功耗。近年来迅速发展的计算机、通信、嵌入式或便携式设备中集成电路的高性能低功耗运行都离不开集成电路版图的精心设计，现代集成电路设计中发展起来的全定制与 ASIC 设计、单元库和 IP 库的建立，以及系统芯片（SoC）设计的新概念和方法学也无一不与集成电路版图设计密切相关。

集成电路版图设计是一门技术，它需要设计者具有电路系统原理与工艺制造方面的基础知识。但它更需要设计者的创造性、空间想象力和耐性，需要设计者长期工作的经验和知识的积累，需要设计者对日新月异的集成电路发展密切关注和探索，总之，集成电路版图设计不仅仅是一门技术，也是一门艺术。设计出一套符合设计规则的“正确”版图也许并不困难，但要设计出最大程度体现高性能低功耗低成本、能实际可靠工作的芯片版图却不是一朝一夕能学会的事情。《集成电路版图设计》（IC Mask Design）一书正是从这些角度出发，力图为读者刻画出集成电路版图设计的一幕幕生动活泼的场景，充分展示作者和其他版图设计工程师在多年设计实践中所积累和总结的经验，提供许多在一般电子学教科书和参考书中没有的材料，使读者能在尽可能短的时间内掌握集成电路版图设计的基本规律和技巧，在自己的

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工作中得益和发展。

本书可作为本科生和研究生有关集成电路设计方面课程的教科书或指导书，以及从事电路和版图设计的工程技术人员的参考书。全书共分为11章，覆盖了模拟电路、数字电路、标准单元、高频电路、双极型和射频集成电路的版图设计技术，讨论了版图设计中有关匹配、寄生参数、噪声、布局、验证、封装等问题及数据格式，最后还提供了两个实际的例子，CMOS放大器与双极型混频器的版图设计。这些精心组织的材料不仅提供了版图设计一步一步的细节指导，有利于读者深刻理解版图设计的全过程，而且也展示了在版图设计中的关键技术，使读者可直接应用于日常的工作中。

作者以轻松幽默的文笔为读者提供了一本图文并茂、实用易读的版图设计参考书，它无疑会开阔您的眼界、拓展您的思路、启发您的创新意识，从而更能激起您对于版图设计工作，一项极有价值工作的热爱。

周润德

2003年11月

于清华大学

Introduction

Mask design techniques have developed at an enormous rate. As circuit speeds increase, the mask designer is expected to quickly, efficiently, and accurately translate a schematic into layout, make informed choices based on knowledge of increasingly complex tools, and understand how circuit function can affect layout decisions. Mask design has evolved into a highly valued profession.

Are your skills as sharp as they could be? Are you highly valued?

IC Mask Design: Essential Layout Techniques provides step-by-step detailed guidance on every aspect of the mask design process, including techniques you will use on a daily basis.

This book is written for mask designers and circuit designers alike. A circuit designer who understands layout techniques can help improve circuit function and reduce design times. The mask designer who understands the roles of communication, teamwork, and knowledge of circuit function as they apply to integrated circuit layout can help produce an integrated circuit with superior performance. A good mask designer is crucial to the development of superior integrated circuits.

IC Mask Design covers matching, noise issues, high frequency layout concerns, analog and digital layout, Bipolar RFIC layout techniques, and much more. Two Case Studies included with this book provide insight into the mask design process, demonstrating essential techniques in action. All material is presented in an enjoyable light style, easily readable, with emphasis on practical application.

We hope this book is horizon-expanding for you. We hope you learn to question, to be creative, to think, to innovate, and to become a critical team player

in designing successful products at your site. Above all, we hope you love your job.

Keep your sense of humor. Enjoy the book.

Christopher Saint
Judy Saint

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Michelle Saint, Jack Pryor, Jack Kennedy, Linda Kennedy, The Pryor Family

Open Letter to Circuit Designers

As a designer, every choice and decision you make within your circuit directly impacts the final piece of silicon that gets built. Circuit design goes beyond the simulator. The physical attributes of your designs can determine whether the circuit thrives or fails. Mask design issues are now, more than ever, part of the circuit design process. Your design is not complete until the circuit is in silicon.

The responsibility of getting your design onto silicon is yours. The responsibility of understanding how your design impacts layout options is yours. The responsibility of communicating circuit requirements to a mask designer is yours. To do all this you must know your mask designers' job as well as they do, if not better.

How can you effectively achieve this difficult part of your job?

First, you need to completely understand your circuit, both electrically and physically. Understanding what your circuit needs to achieve electrically will enable you to make informed decisions about what device sizes to use and what layout techniques to employ. Every time you place a device or an interconnect in your schematic you should be thinking, "What will this look like physically?" You should live, breathe, and think mask design. Every waking thought should be how your circuit will be physically implemented.

Second, you need to understand your manufacturing process intimately—how every component in the process is built and used. If you understand your process, you can make intelligent choices that are based upon documented behaviors instead of wild guesses. Know your manuals. Check your equations. Bother to look them up.

Above all, make sure that your mask designers get all the information they need to do their job effectively. A trap many circuit designers fall into is that they seem to consider a schematic capture tool as merely an electronic front

end to their simulation software. Instead, the schematic database should be considered as the primary source of documentation for a chip design. The following schematic practices can greatly improve any project and reduce rework:

- Annotate current values and paths
- Add layout notes to your schematic
- Place the circuit name onto the schematic
- Keep an effective revision history on the schematic (particularly dates and times)
- Make schematics readable when printed out

This list of practices will not only make your schematics more usable for a mask designer, but also for any subsequent circuit designers who may wish to reuse your innovative, world-shattering concepts.

A small warning: Be careful to choose your mask design techniques wisely. It is easy to overburden your mask designer unnecessarily. For example, if your circuit requires that two resistors match each other to within 5%, then why bother specifying the use of a complex layout technique to produce a match of better than 1%? The increased matching you achieve does not make your circuit any better, but does require extra effort during the mask design phase. Circuit designers who blindly require a mask designer to apply every layout technique in the book (e.g., this one) on their components are potentially costing their company money due to the increased design cycle times.

Know what needs to be communicated to your mask designer. Know how your mask designer can help you. A mask designer is a valuable resource and has probably had extensive exposure to many different circuit design and layout techniques during his or her career. Use that resource. Work as a team. Communicate. Listen. Suggest. Explain. Annotate. Calculate. Learn. Did I say communicate? Especially communicate.

Good layout means successful circuits. If you follow these simple concepts and ideals you will become a cut above the rest. Use this book to build your skills and learn the language of mask design. Today's competetive marketplace demands it.

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Essential Layout Techniques

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