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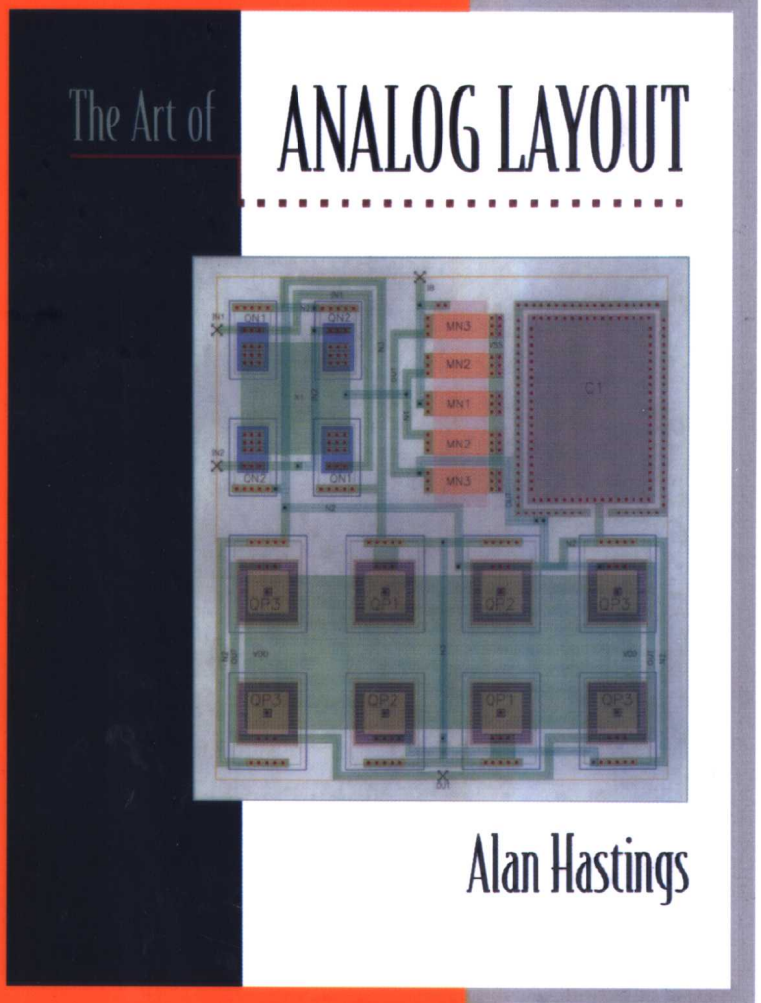
Alan Hastings

模拟电路版图的艺术



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The Art of Analog Layout

Alan Hastings

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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。

清华大学出版社
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2003.9

I A	II A	III B	IV B	V B	VI B	VII B	VII	VII	VII	I B	II B	III A	IV A	V A	VI A	VII A	0
1 **H** Hydrogen																	2 **He** Helium
3 **Li** Lithium	4 **Be** Beryllium											5 **B** Boron	6 **C** Carbon	7 **N** Nitrogen	8 **O** Oxygen	9 **F** Fluorine	10 **Ne** Neon
11 **Na** Sodium	12 **Mg** Magnesium											13 **Al** Aluminum	14 **Si** Silicon	15 **P** Phosphorus	16 **S** Sulfur	17 **Cl** Chlorine	18 **Ar** Argon
19 **K** Potassium	20 **Ca** Calcium	21 **Sc** Scandium	22 **Ti** Titanium	23 **V** Vanadium	24 **Cr** Chromium	25 **Mn** Manganese	26 **Fe** Iron	27 **Co** Cobalt	28 **Ni** Nickel	29 **Cu** Copper	30 **Zn** Zinc	31 **Ga** Gallium	32 **Ge** Germanium	33 **As** Arsenic	34 **Se** Selanium	35 **Br** Bromine	36 **Kr** Krypton
37 **Rb** Rubidium	38 **Sr** Strontium	39 **Y** Yttrium	40 **Zr** Zirconium	41 **Nb** Niobium	42 **Mo** Molybdenum	43 **Tc** Technetium	44 **Ru** Ruthenium	45 **Rh** Rhodium	46 **Pd** Palladium	47 **Ag** Silver	48 **Cd** Cadmium	49 **In** Indium	50 **Sn** Tin	51 **Sb** Antimony	52 **Te** Tellurium	53 **I** Iodine	54 **Xe** Xenon
55 **Cs** Cesium	56 **Ba** Barium	57 **La** Lanthanum	72 **Hf** Hafnium	73 **Ta** Tantalum	74 **W** Tungsten	75 **Re** Rhenium	76 **Os** Osmium	77 **Ir** Iridium	78 **Pt** Platinum	79 **Au** Gold	80 **Hg** Mercury	81 **Tl** Thallium	82 **Pb** Lead	83 **Bi** Bismuth	84 **Po** Polonium	85 **At** Astatine	86 **Rn** Radon
87 **Fr** Francium	88 **Ra** Radium	89 **Ac** Actinium															

Lanthanides	58 **Ce** Cerium	59 **Pr** Praseodymium	60 **Nd** Neodymium	61 **Pm** Promethium	62 **Sm** Samarium	63 **Eu** Europium	64 **Gd** Gadolinium	65 **Tb** Terbium	66 **Dy** Dysprosium	67 **Ho** Holmium	68 **Er** Erbium	69 **Tm** Thulium	70 **Yb** Ytterbium	71 **Lu** Lutetium
Actinides	90 **Th** Thorium	91 **Pa** Protactinium	92 **U** Uranium	93 **Np** Neptunium	94 **Pu** Plutonium	95 **Am** Americium	96 **Cm** Curium	97 **Bk** Berkelium	98 **Cf** Califomium	99 **Es** Einsteinium	100 **Fm** Fermium	101 **Md** Mendelevium	102 **No** Nobelium	103 **Lr** Lawrencium

Preface

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 require a thorough understanding of the principles of device physics, semiconductor fabrication, and circuit theory. Despite thirty years of research, much remains uncertain. What information there is lies buried in obscure journal articles and unpublished manuscripts. This textbook assembles this 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 using pencil and paper.

The text consists of fourteen 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 Five and Six cover the layout of resistors and capacitors. Chapter Seven presents the principles of matching, using resistors and capacitors as examples. Chapters Eight through Ten cover the layout of bipolar devices, while chapters Eleven and Twelve cover the layout and matching of field-effect transistors. Chapters Thirteen and Fourteen 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, Lou Hutter, Clif Jones, 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 text would never have been written.

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