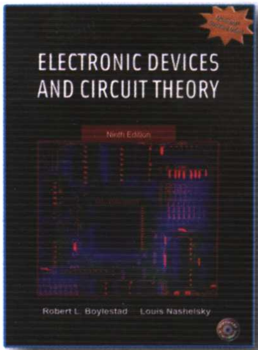
国外电子与通信教材系列

英文版

模拟电子技术

Electronic Devices and Circuit Theory

Ninth Edition



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北京·BEIJING

内 容 简 介

本书是一本优秀的模拟电子电路基础英语原版教材（第九版）的改编版，内容包括半导体器件基础，二极管及其应用电路，晶体管和场效应管放大电路的基本原理及频率响应，功率放大电路，多级放大电路、差分放大电路、电流元等模拟集成电路的单元电路，反馈电路，模拟集成运算放大器，电压比较器和波形变换电路等。在原版内容的基础上，改编版结合国内高等教育中采用英语或双语教学的特点和实际情况，对部分内容进行了删减和补充，适合40到68学时的教学要求。

本书内容简明扼要、深入浅出且示例丰富，采用原版英语，语言生动流畅，可作为电子、通信、信息等领域相关课程的本科生英语、双语教学教材或教学参考书，也可供相关专业的工程技术人员学习和参考。

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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。

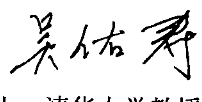
我国领导部门对教材建设一直非常重视。20世纪80年代，在原教委教材编审委员会的领导下，汇集了高等院校几百位富有教学经验的专家，编写、出版了一大批教材；很多院校还根据学校的特点和需要，陆续编写了大量的讲义和参考书。这些教材对高校的教学工作发挥了极好的作用。近年来，随着教学改革不断深入和科学技术的飞速进步，有的教材内容已比较陈旧、落后，难以适应教学的要求，特别是在电子学和通信技术发展神速、可以讲是日新月异的今天，如何适应这种情况，更是一个必须认真考虑的问题。解决这个问题，除了依靠高校的老师和专家撰写新的符合要求的教科书外，引进和出版一些国外优秀电子与通信教材，尤其是有选择地引进一批英文原版教材，是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

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”。

为做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。

电子工业出版社

教材出版委员会

改 编 者 序

本书是根据 *Electronic Devices and Circuit Theory, Ninth Edition* 改编的英文版教材，适合电子电路基础相关课程40学时到68学时的英语或双语教学使用。

本书的两位作者Robert L. Boylestad和Louis Nashelsky都是在大学从事电路分析、电子电路基础等相关学科教学的资深教授，在电子电路学科领域出版了多部优秀教材，受到很高的评价。本书自1972年首次出版后，被多所大学作为教材使用，经过不断实践与修订，涵盖了广泛和新颖的内容，成为流行30多年的优秀经典教材。

Electronic Devices and Circuit Theory, Ninth Edition 的内容体系与国内高校电子电路基础相关课程的教学内容有较高的一致性，基于这一点，本人于2005年采用原版教材在北京邮电大学国际学院开展了电子电路基础的双语教学，获得了教师和学生的好评。但是，通过亲自实践以及进一步考察国内高校相关学科开展双语教学的情况，也发现本书与国内高校的教学内容和课程安排存在一定不协调之处。自国内高校教育改革以来，大部分院校的专业基础课程在学时上受到一定程度的压缩。在有限的学时下，本书的内容显得较为庞大。例如，振荡器和锁相环等知识在国内高等院校大都是高频或非线性电子电路等课程的内容；数字集成电路基础及其应用电路也是国内高校的数字电路与逻辑设计相关课程的内容；器件知识较多，占据了较大篇幅（原第16章和第17章）的内容，但在国内电子电路基础课程教学中通常很少涉及这些内容，或者属于非重点内容；电子电路EDA分析和设计，在国内一般属于实验课程的内容。

为了使教材内容更合理，范围宽窄适度，内容深浅适中，进而满足国内和国际高等教育相关专业电子电路基础课程的教学要求，适应国内教育教学特色，并便于学生在有限学时下把握重点，深入理解，我们以精简内容和突出重点为目标对这本书进行了改编。改编版的前10章和第12章主要删减了计算机辅助分析的示例以及一些仪器仪表的使用，除个别小节与习题的调整以外，大部分内容与原书基本一致，主要包括：半导体器件基础，半导体二极管及其应用电路，双极型晶体管BJT基础及其直流、交流分析，场效应晶体管FET基础及其直流、交流分析，BJT和FET放大电路的频率响应，模拟集成运算放大器基础和功率放大器等。改编版的第11章融合了原版第11章和第13章的内容，去掉了数字集成电路的内容，并将应用电路进行了精简，使得改编后的第11章主要包括模拟集成运算放大器、电压比较器等常见模拟集成电路的应用电路。考虑到国内院校通信专业需要学习施密特触发器及波形变换电路，将此知识点在改编版的第11章也进行了补充。改编版的第13章来自原版第14章的内容，主要包含反馈的基本概念和负反馈放大电路分析。对于构成振荡器的正反馈电路进行了删减。原版书第15章涉及的内容，其基本原理已经在第2章进行了介绍，而且根据国内高校电子电路基础相关课程的教学大纲，不

属于重点内容，因此在改编版中不再出现。原版第16章和第17章内容主要讲解多种电子器件知识，而这部分内容在国内高校电子电路基础相关课程内容中较少涉及，因此在改编版中不再出现。此外，改编版中不再提供习题答案、索引等内容。习题答案等可在相关网站获得，详细情况参见本书 Preface 的 SUPPLEMENTS 小节。原有教材附录中的参数计算知识可参考正文部分及相关参考书籍。

在本书的改编过程中，一方面结合了本人在北京邮电大学国际学院开展电子电路基础课程双语授课的实践经验，另一方面，北京邮电大学蔺志清教授、刘宝玲教授和已退休的张春茂教授都给予本人许多帮助和指导，在此表示衷心感谢！

李立华
北京邮电大学
2007年8月

Preface

This ninth edition of *Electronic Devices and Circuit Theory* represents a number of important changes to the text. In addition to organizational changes that ensure a flow of material to support current trends in the teaching and learning processes, substantial updates in content are made to provide the latest information in technologies and material science. Specific areas of investigation are rewritten to ensure that the salient points are emphasized rather than lost in superfluous material. Practical examples are carefully rewritten to reflect current trends in the marketplace and provide a realistic, contemporary glimpse into how the components can be used.

The most noticeable change is the combination of Chapters 7, 8, 10, and parts of 12 of the eighth edition into one new chapter (Chapter 5), on the subject of small signal BJT analysis. At first glance, this consolidation might suggest that the chapter is now enormous and unwieldy. However, the rewriting of specific sections, deletions of some unnecessary derivations, and removal of sections no longer relevant have resulted in a presentation that is more palatable for students as well as instructors. The entire analysis of small-signal BJT analysis for single and multistage transistor networks is now covered in one chapter.

In addition to this reorganization, another change of significance entails the rearrangement of chapter sequence such that coverage of dc analysis of BJT networks and FET networks is now included in the chapter preceding the ac analysis of each. This is important because the dc analysis of each has a direct effect on the ac results. Removing the delay in coverage between the dc and ac analysis improves the transition from one subject matter to the other. (In prior editions, the dc analysis of both the BJT and FET devices was covered in total before moving on to the ac material for each.)

As also indicated, the major changes are in the sequence of coverage and the combining of various chapters. However, it is important to realize that the topics of GaAs, op-amps, and zener devices all receive a broader range of coverage in keeping with developments in the field. In the high-frequency analysis sections, the use of the hybrid π model is expanded at the request of current users and reviewers. In the ac analysis sections, the controlled sources all have the diamond shape as dictated by current standards and their increasing use in the classroom and software packages.

Overall, the changes in some chapters are significant, whereas in others they are very limited. In particular, Chapter 1 is almost totally rewritten to improve the presentation of the introductory material and to add significant information on gallium arsenide materials. Other chapters, such as the introduction to BJTs and FETs, remain untouched because current users are, in general, pleased with the content.

Throughout the preparation of this ninth edition, the authors have maintained the technical accuracy of this text. There is nothing more frustrating to the teacher or student than to find errors in solutions or derivations. The authors are very pleased that the number of corrections found in the classroom or submitted by users is so small that they now feel the text is as error-free as possible for a published text. Of course, they would deeply appreciate receiving any comments about derivations, results, or conclusions that might raise concern.

FEATURES

- ***Systems approach*** As in the prior edition, every effort is made to enhance the material that introduces the concept of system engineering. For ac analysis, the difference between the no-load and loaded gain is emphasized with examples of how each affects the gain and characteristics of a system. Entire sections remain to demonstrate the impact of the source and load resistance on the system response, although now the material is an integral part of the ac analysis chapter of the device under discussion.
- ***Visual presentation*** This text represents a concerted effort to ensure that important statements and conclusions stand out in boldface and/or color. Color is used for instructional purposes wherever appropriate to identify important parameters, network regions, and results — and to enhance the understanding of figures. The format in general has been chosen to improve readability. Summaries and equation lists appear near the end of each chapter for review and study. Illustrations of the use of color and the chapter summaries and equation lists appear in Fig. P-1.

input and output networks. Although the feedback resistor is usually many times that of the source resistance, permitting the approximation that the source resistance is essentially 0 Ω, it does present a situation where the source resistance could possibly affect the output resistance or the load resistance could affect the input impedance. In general, however, due to the high isolation provided between the gate and the drain or source terminals, the general equations for the loaded gain are less complex than those encountered for BJT transistors. Recall that the base current provided a direct link between input and output circuits of any BJT transistor configuration.

To demonstrate each approach, let us examine the self-bias configuration of Fig. 8.43 with a bypassed source resistance. Substituting the ac equivalent model for the JFET results in the configuration of Fig. 8.44.

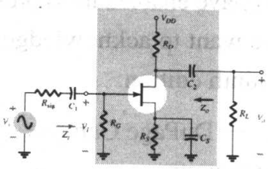


Fig. 8.43 JFET amplifier with R_{sig} and R_L.

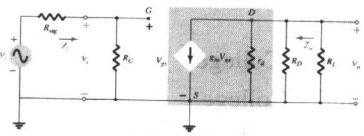


Fig. 8.44 Network of Fig. 8.43 following the substitution of the ac equivalent circuit for the JFET.

Note that the load resistance appears in parallel with the drain resistance and the source resistance R_{sig} appears in series with the gate resistance R_G. For the overall voltage gain the result is a modified form of Eq. (8.21):

$$A_v = \frac{V_o}{V_i} = -g_m(r_d \| R_D \| R_L) \tag{8.61}$$

The output impedance is the same as obtained for the unloaded situation without a source resistance:

7.10 Summary

Important Conclusions and Concepts

1. A fixed-bias configuration has, as the label implies, a **fixed** dc voltage applied from gate to source to establish the operating point.
2. The **nonlinear** relationship between the gate-to-source voltage and the drain current of a JFET requires that a graphical or mathematical solution (involving the solution of two simultaneous equations) be used to determine the quiescent point of operation.
3. All voltages with a single subscript define a voltage from a specified point to **ground**.
4. The self-bias configuration is determined by an equation for V_{GS} that will always pass through the origin. Any other point determined by the biasing equation will establish a **straight** line to represent the biasing network.
5. For the voltage-divider biasing configuration, one can always assume that the gate current is 0 A to permit an **isolation** of the voltage-divider network from the output section. The resulting gate-to-ground voltage will always be **positive for an *n*-channel JFET** and **negative for a *p*-channel JFET. Increasing values of R_S** result in **lower quiescent values of I_D** and more **negative values of V_{GS} for an *n*-channel JFET**.
6. The method of analysis applied to depletion-type MOSFETs is the same as applied to JFETs, with the only difference being a possible operating point with an I_D level **above** the I_{DSS} value.
7. The characteristics and method of analysis applied to enhancement-type MOSFETs are **entirely different** from those of JFETs and depletion-type MOSFETs. For values of V_{GS} less than the threshold value, the drain current is 0 A.
8. When analyzing networks with a variety of devices, first work with the region of the network that will provide a **voltage or current level** using the basic relationships associated with those devices. Then use that level and the appropriate equations to find other voltage or current levels of the network in the surrounding region of the system.
9. The analysis of *p*-channel FETs is the same as that applied to *n*-channel FETs except for the fact that all the voltages will have the **opposite polarity** and the currents the **opposite direction**.

Equations

JFETs/depletion-type MOSFETs:

Fixed-bias configuration: $V_{GS} = -V_{GG} = V_G$

Self-bias configuration: $V_{GS} = -I_DR_S$

Voltage-divider biasing: $V_G = \dfrac{R_2V_{DD}}{R_1 + R_2}$

$V_{GS} = V_G - I_DR_S$

Enhancement-type MOSFETs:

Feedback biasing: $V_{DS} = V_{GS}$

$V_{GS} = V_{DD} - I_DR_D$

Fig. P-1

SUPPLEMENTS

To enhance the learning process, a full supplements package accompanying this text is available to students and instructors using the text for a course.

Student Resources

- Laboratory Manual (PSpice® Emphasis), ISBN 0-13-118906-9
- Laboratory Manual (Multisim® Emphasis), ISBN 0-13-172088-0
- Companion Website (student study guide) at **www.prenhall.com/boylestad**

Instructor Resources

- Instructor's Resource Manual (containing text and lab solutions and test item file), ISBN 0-13-118907-7
- PowerPoint® Lecture Notes, ISBN 0-13-118908-5
- TestGen®, an electronic test bank, ISBN 0-13-118915-8

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Semiconductor Diodes

Chapter Outline

1.1 Introduction

One of the noteworthy things about this field, as in many other areas of technology, is how little the fundamental principles change over time. Systems are incredibly smaller, current speeds of operation are truly remarkable, and new gadgets surface every day, leaving us to wonder where technology is taking us. However, if we take a moment to consider that the majority of all the devices in use were invented decades ago and that design techniques appearing in texts as far back as the 1930s are still in use, we realize that most of what we see is primarily a steady improvement in construction techniques and application of those devices rather than the development of new elements and fundamentally new designs. The result is that most of the devices discussed in this text have been around for some time, and that texts on the subject written a decade ago are still good references with content that has not changed very much. The major changes have been in the understanding of how these devices work and their full range of capabilities, and in improved methods of teaching the fundamentals associated with them. The benefit of all this to the new student of the subject is that the material in this text will, we hope, have reached a level where it is relatively easy to grasp and the information will have application for years to come.

The miniaturization that has occurred in recent years leaves us to wonder about its limits. Complete systems now appear on wafers thousands of times smaller than the single element of earlier networks. The first integrated circuit (IC) was developed by Jack Kilby while working at Texas Instruments in 1958 (Fig. 1.1). Today, the Intel® Pentium® 4 processor shown in Fig. 1.2 has more than 42 million transistors and a host of other components. Recent advances suggest that 1 billion transistors will soon be placed on a sliver of silicon smaller than a fingernail. We have obviously reached a point where the primary purpose of the container is simply to provide some means for handling the device or system and