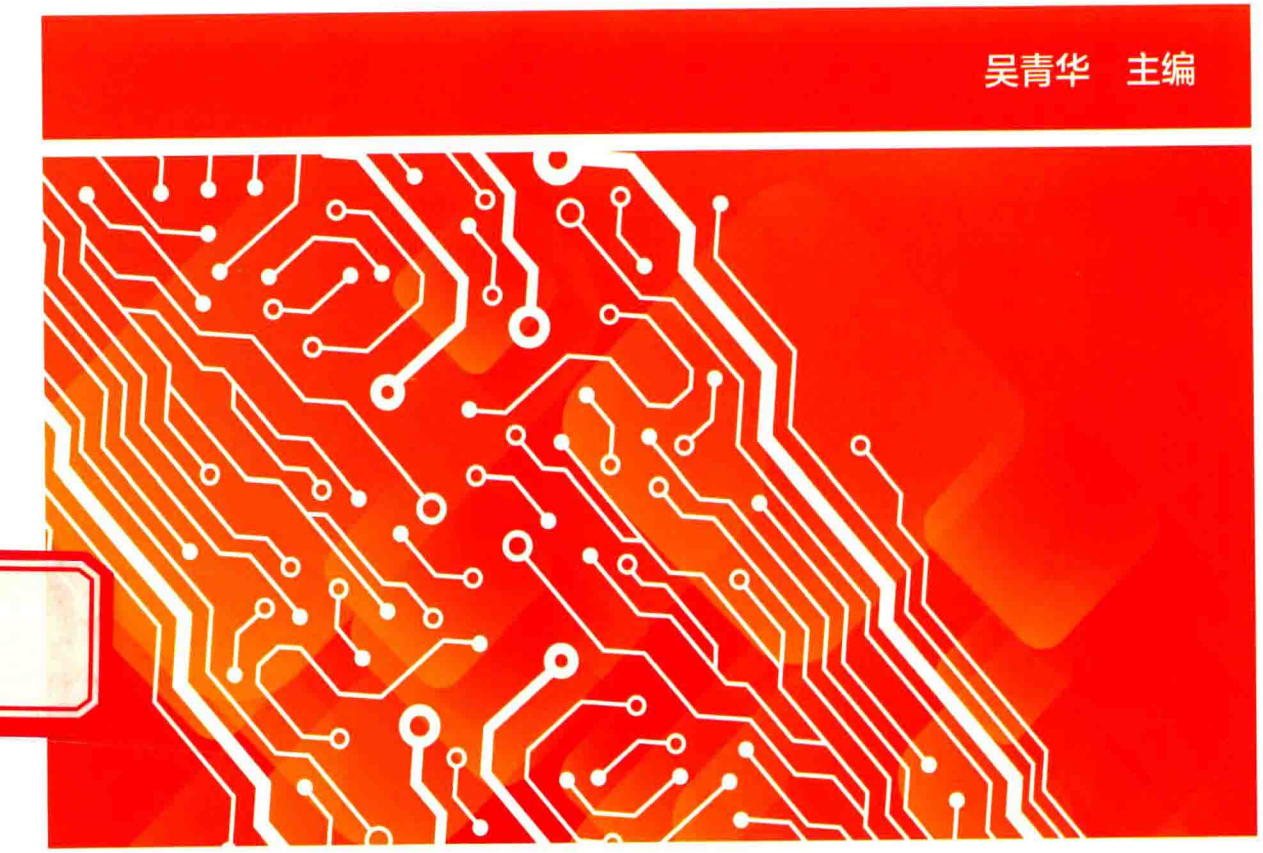
电气工程基础双语教材

Electrical Engineering Fundamentals

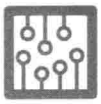
电路与电子技术

Electric Circuits and Electronics

吴青华 主编



中国电力出版社
CHINA ELECTRIC POWER PRESS



电气工程基础双语教材

Electrical Engineering Fundamentals

电路与电子技术

Electric Circuits and Electronics

吴青华　主编

季天瑶　樊利民　贺小勇　李梦诗　编写

中国电力出版社

CHINA ELECTRIC POWER PRESS

内 容 提 要

本书为电气工程基础双语教材。全书内容分为电路与电子技术两部分，共 11 章，主要内容包括绪论、电路及其基本物理量与元件、电压与电流定律、经典电路分析方法、直流稳态与暂态分析、正弦电路稳态分析、三相电路、二极管、双极型三极管、场效应管、运算放大器、逻辑电路等。每章均配有相应的课堂讨论环节，给学生提供机会进行学术英语的思维、口语表达及演讲的训练，帮助学生对所学知识活学活用，将理论与生产生活实际结合起来。

在部分章节中加入了与当代工程技术相结合的应用实例分析，阐述电路及电子技术在实际应用中的原理及技术最前沿的发展方向，有助于学生了解工程应用中各类型电路与设备及其分析设计方法，达到学以致用。为配合教学与读者自学，本书配有电子课件及习题答案。

本书可作为开设“电路与电子技术”双语或全英语教学的电气类、电子信息类、自动化类等专业教材，也可作为其他工科专业的选修教材及供电路与电子技术及电类科技英语有兴趣的读者阅读与参考。

图书在版编目（CIP）数据

电路与电子技术=Electrical Engineering Fundamentals：Electric Circuits and Electronics：汉、英 / 吴青华主编. —北京：中国电力出版社，2017.2

电气工程基础双语教材

ISBN 978-7-5123-8433-0

Ⅰ. ①电… Ⅱ. ①吴… Ⅲ. ①电路理论－双语教学－高等学校－教材－汉、英②电子技术－双语教学－高等学校－教材－汉、英 Ⅳ. ①TM13②TN01

中国版本图书馆 CIP 数据核字（2015）第 243184 号

中国电力出版社出版、发行

（北京市东城区北京站西街 19 号 100005 http://www.cepp.sgcc.com.cn）

汇鑫印务有限公司印刷

各地新华书店经售

*

2017 年 2 月第一版 2017 年 2 月北京第一次印刷

787 毫米×1092 毫米 16 开本 15.75 印张 384 千字

定价 **38.00** 元

前 言

由于现代工科源于西方科学技术的发展成果，高等院校工科教学一贯基于西方体系，科技术语多来自英文翻译，因此本科阶段对工科学生进行科技英语读写训练非常必要。培养学生英文表达能力的同时，让学生了解知识的本源，为将来在国际期刊发表科技论文打下基础。然而由于课时量的限制，仅通过“科技英语”课程无法完成此任务，因此面向本科生开设双语课程成为大势所趋，并且急需针对中国学生语言和逻辑思维背景的双语教材与之相配合。

本书以中英文对照的方式编写，方便读者阅读。全面介绍了电路与电子技术的基本概念和基本定律、电子电路的基本应用及其分析设计方法，使学生获得必要的电路与电子学基本概念和基本定律知识，掌握基本分析、设计方法，了解电路与电子技术发展的概况，建立坚实的电路分析基础，并具备一定的电路设计能力。本书内容分为电路与电子技术两部分，主要内容包括电路及其基本物理量与元件、电压与电流定律、经典电路分析方法、直流稳态与暂态分析、正弦电路稳态分析、三相电路；二极管、双极型三极管、场效应管、运算放大器、逻辑电路。本书突出概念及定义，将电路与电子技术领域内的经典理论和分析方法，必要时通过类比的方法阐述，以便于读者理解。每章均配有相应的讨论环节，给读者提供机会进行学术英语的思维、口语表达及演讲的训练，帮助读者对所学知识活学活用，将理论与生产、生活实际结合起来。在部分章节中加入“实例分析”，通过具体的案例阐述电路及电子技术在实际中的应用，有助于读者了解工程应用中各类型电路的分析设计方法，学以致用。在相应地方介绍科学家的简历和背景故事，寓教于乐。

作为工科基础课之一，本书面向电气信息类、电子信息类、自动化类专业的本科生，适用于课程设置中设有“电路与电子技术”双语或全英必修课的专业，也适用于其他专业的“电路与电子技术”选修课，也可作为广大对电路与电子技术这门学科、对电类科技英语有兴趣的读者的科普读物。

全书共分为 11 章，第 1、4、5、6、9 章由季天瑶编写，第 2、3 章由樊利民编写，第 7、8 章由贺小勇编写，第 10、11 章由李梦诗编写。本书由华南理工大学吴青华教授主编

并统稿，中科院深圳先进技术研究院英籍博士 Peter Z Wu 仔细阅读了本书英文部分并给出了专业的修改意见，香港大学侯云鹤副教授对本书提出了切实的审稿意见，在此表示衷心的感谢诚恳希望广大读者对本书的缺点和错误提出批评和指正。

注意：本书以英文为主，中文只用来辅助英文理解，为了排版美观，英文部分加入了部分拓展的课外知识，没有给出对应的中文翻译；将图表放入了中文部分，节约版面的同时，图表中给出了中文、英文对应图表名及图注，方便查阅。

编者

Preface

The advacements of modern industry and engineering stem from the gradual developments of science and technology in the western world. Teaching of engineering in colleges and universites has always been based on the western education system, and many terminologies are translated from English. Therefore, it is of great necessity to train engineering students in academic reading and writing using the English language, which will enable the students to gain a better understanding of the subject matter at its root level and later on prepare them for publishing research papers in international journals. However, due to the limited class hours, relying solely on the attendance of compulsory courses such as academic English is insufficient to fulfill such a task. A better approach is to open bilingual courses to undergraduate students. Hence, textbooks written in both English and Chinese, which fully consider the language and train of thought of Chinese students, are in urgent need.

To ensure the readability of the textbook for students, it is typeset so that Chinese content is displayed on the left and the corresponding English content is shown on the right. This book covers the basic concepts and principles of electrical circuits and electronics, practical applications of circuits, and the analysis as well as design of circuits. This book will enable readers to understand basic laws and principles, apply them to solve and design circuits, get to know the historical development of electrical circuits and electronics. It provides a sound base to enable readers to develop theoretical and experimental skills in the areas covered. The book consists of two parts—electrical circuits and electronics, including basic elements and circuits, nonlinear elements, voltage and current laws, circuit analysis methods, DC steady state and transient analysis, ac steady state analysis, three-phase circuits; diodes, BJT transistors, MOSFET transistors, operational amplifiers, logic circuits. The book focuses on basic concepts and definitions, presentation of theories and analysis methods in the areas mentioned above, where appropriate illustrations are provided to assist the readers' understanding of a concept. Discussions are also available in most chapters, which will help readers with the practical application of theories, as well as providing them with opportunities to practice their academic presentation skills. Some chapters also include examples explaining the application of electric circuits and electronics to solving real-world problems and demonstrate how the circuits are analyzed and designed in engineering. Relevant great scientists and engineers are introduced with their contributions highlighted.

As an elementary course for engineering students, this textbook is suitable for undergraduate students majoring in the subject of computer science, software engineering, automation, cybernetics, as well as other specialist subjects where the course of electrical citruits and electronics is mandatory and taught bilingual or in English. In addition, this textbook can also serve as an introduction for readers who are interested in electrical circuits and electronics and in academic English regarding electricity.

The book is organized into 11 chapters. The contributions made by each of the co-authors are

listed as follows: chapters 1,4,5 and 9 were written by Dr. Tianyao Ji. Chapters 2 and 3 have been supplied by Limin Fan, while chapters 7 and 8 were written by Xiaoyong He. Chapters 10 and 11 were contributed by Dr. Mengshi Li. Prof. Qing-Hua Wu from South China University of Technology edited the completed book. Dr. Peter Z Wu from Shenzhen Institutes of Advanced Technology, Chinese Academy of Sciences has proofread the English version and made meticulous corrections to ensure its readability. Dr. Yunhe Hou from Hong Kong University has reviewed the book and provided useful comments. The authors would like to ackonwledge the help and encouragement that have been provided to them during the writing of this book.

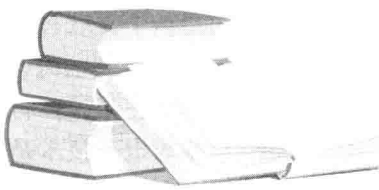
Readers are welcome to address comments and corrections.

the authors

目 录

Contents

绪　论
Introduction



古希腊人通过摩擦琥珀感受到了轻微电击，18 世纪初的欧洲人将产生静电视为神奇的魔术表演，18 世纪中期富兰克林设计的实验揭示了闪电本质上与人们发现的“电”一样，18 世纪末伏特首次发明了电池。从此，关于电的科学研究一直在飞速发展。电是一种大家最熟悉的能源，我们利用电能点亮城市，利用电能取暖度过漫长冬夜，跨过大陆长空传递信息，创造现代工业和引领数字革命。耳熟能详的领域如通信、计算机、控制系统、电磁学、电力系统等都与电有关。本书将介绍上述专业共同的基础——电路与电子技术，介绍电路和电子学的基本概念和基本定律、电路的基本应用及其分析设计方法。通过学习本书，读者可以了解电路与电子技术发展的概况，打下坚实的硬件基础，为在其他相关领域的进一步深造做好准备。

电气工程是工科的一个分支，几乎涵盖了所有与电有关的应用，包括电工学、电子学、电磁学。现今通常将电气工程分为如下领域：电子学、计算机、电力系统、通信、控制系统、信号处理、电磁学、微电子等。电子学主要研究电子的特性和行为，应用电子学的原理设计制造电路和电子器件。计算机是最常见的电子设备之一，其功能的实现离不开电路。电力系统主要涉及电能的生产、传输、配送和使用。通信是研究信息以电的形式进行传播的科学，比如电报、电话、无线广播、卫星电视、因特网等。控制系统通过传感器获得需要的信息，再根据这些信息利用电能控制其他设备动作。信号处理指对包含了信息的电信号进行处理，其目的是从中提取有用的信息。电磁学是一门研究电和磁相互作用的学科，主要研究电磁波、电磁场以及有关电荷、带电物体的动力学等。微电子研究和制造微小的电子电路和元件，电子电路集成在半导体材料上，使得电路尺寸减小，功耗降低，性能提升。

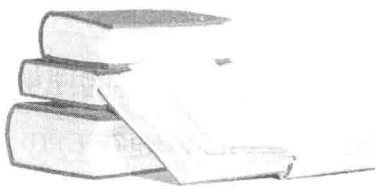
电路与电子技术是电气工程的基础课程。本书的前 6 章构成第一部分，主要介绍电路的基本概念和基础知识，读者将从最基本的原理开始，逐步学会复杂电路的分析和设计；后 5 章构成本书的第二部分，主要介绍各类基本非线性元件和简单电子电路，并应用在第一部分学到的电路分析方法对其进行分析。

The ancient Greeks experienced minor shocks of electricity by rubbing together amber; in the early 1700s, people from Europe regarded static electricity as an astonishing form of magic; in the mid-1700s, an experiment designed by Franklin revealed that lightning by its nature was the same as the electricity made by man; in the late 18th century, Volta invented the first battery in the world. From then on, research on electricity has been rocketing. We use electricity to light our cities, heat our flats during cold winter nights, communicate across vast lands and oceans, as well as create modern industries and bring about the digital revolution. Fields such as commutation, computers, control systems, electromagnetism and power systems can all trace their roots back to the discovery of electricity. This book will introduce the foundation for all these fields—electrical circuits, including the fundamental concepts and laws of electrical circuits and electronics, the applications of electrical circuits, together with how to analyze and design circuits. This book will help you to understand the construction of electrical circuits and electronics, gain solid background in hardware, and prepare you for further study in related fields.

Electrical engineering is a branch of engineering that involves the study and application of electricity, electronics, and electromagnetism, which has now been subdivided into a wide range of subfields, including electronics, digital computers, power systems, telecommunications, control systems, signal processing, electromagnetism, microelectronics, etc. Electronics studies the characteristics of electrons and designs electronic circuits and devices. Computers are one of the most commonly used electrical devices, where circuits are designed to allow computers to perform complex computations. Power systems deal with the generation, transmission, distribution and utilization of electric power. Telecommunication is the transmission of information in electrical form, such as telegraph, telephone, radio, satellite television, the Internet, etc. Control systems gather information via sensors and use electrical energy to control a physical process. Signal processing involves the processing of electrical signals that carry information, and its objective is to extract useful information from these signals. Electromagnetism is concerned with the study of interaction between electricity and magnetism, including electromagnetic waves, electromagnetic fields, physical interaction that occurs between electrically charged particles. Microelectronics relates to the study and manufacture of very small electronic designs and components, and circuits are integrated in semiconductor material, which ensures the circuits to have smaller size, lower power consumption and better performance.

Electrical circuit and electronics is a fundamental course for electrical engineers. The first six chapters of this book focus on the basic concepts and fundamental knowledge of electrical circuits. We will start from the fundamental principles and then learn to analyze more complex circuits. In the second part, from Chapters 7 to 11, we will learn about nonlinear electronic devices and solve electronic circuits, using the circuit analysis methods we have learnt in the first part.

第1章
Chapter 1



电路及其基本物理量与元件
Circuits and its Basic Physical Variables and Elements

1.1 电路

手电筒电路可以说是一个最简单的电路实例，它由一块电池、一只灯泡、一个开关和几条将这些元件连成一个闭合回路的导线组成，如图 1.1（a）所示。当开关闭合时，电池将化学能转换为电能，这些电能通过导线输送给灯泡，灯泡里的钨丝则将电能转换为光和热。当开关断开时，能量的转换和传输被切断，灯泡不发光。

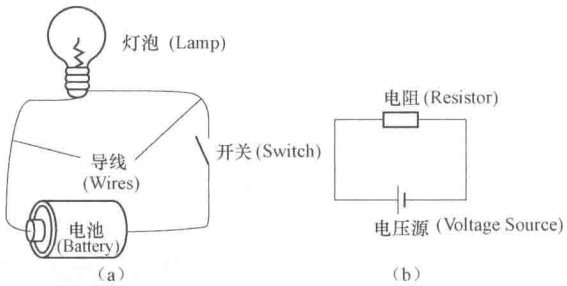


图 1.1　手电筒电路

（a）手电筒电路的示意图；（b）相应的电路图

Fig. 1.1　A torch circuit

(a) An illustration circuit; (b) The circuit diagram

手电筒电路的电路原理图如图 1.1（b）所示。在图 1.1（b）中，电池用一个电压源表示，灯泡被抽象为一只电阻，开关被省略（因为通常我们只考虑电路闭合时的情况），导线用线段表示。电压源和电阻称为电路元件。除这两种外，常用电路元件还有电流源、电感和电容，它们的性质将在后续章节中介绍。电路分析的目的就是在已知电路构成的情况下，求解某些物理量（如流过电阻的电流或电容两端的电压等）或某些电路元件的参数（如电阻的阻值等）。

1.2 基本物理量

1.2.1 电荷

电荷是电路中最基本的物理量。它是物质原子的基本属性，通常用 q 表示，单位为库仑（简称库，C）。一个电子所带的电荷为 -1.602×10^{-19} C。古希腊人所感受到的那种轻微电击，就是电荷作用的效果。在手电筒电路中，电压源迫使电荷流经导线和电阻。导线由一种导电性能极好的金属（例如铜）做成，这样电荷在通过导线时几乎不会受到阻碍。而电阻的导电性能则差很多，电荷流过电阻时会受到阻碍，将电能转换为热能。

1.2.2 电流

电流的定义为电荷流量随时间变化的速率。假设电荷和电流均是时间的函数并分别表示为 $q(t)$ 和 $i(t)$，则电流、电荷和时间之间的数学关系可表示为

$$i(t)=\frac{\mathrm{d}q(t)}{\mathrm{d}t} \tag{1.1}$$

电流的单位为安培（简称安，A），等同于库仑/秒。若已知电流，则在 t_0 时刻和 t 时刻之间移动的电荷可通过对式（1.1）两端进行积分求得

$$q(t)=\int_{t_0}^{t} i(t)\mathrm{d}t+q(t_0) \tag{1.2}$$

其中 t_0 时刻的电荷为已知。

电流是有方向的。在电路图中，我们通常用箭头表示电流的方向。大多数情况下，在进行电路分析时，并不清楚流过一段导线或流过一个元件的电流是什么方向。这就需要任意假设一个电流的参考方向。通常用不同的下标来区分流过不同元件的电流。如图 1.2 所示，标有 A、B、C、D 的小方框代表了电路元件，流过它们的电流分别用 i_1、i_2、i_3、…表示。