海军工程大学涉外丛书

Warship Electronic Technology Basics

舰艇电子技术基础

主 编 朱旭芳 钟 斌

副主编 马知远 潘 丽 吴文全 范 越

WUHAN UNIVERSITY PRESS

武汉大学出版社

海军工程大学涉外丛书

外训系列教材

Warship Electronic Technology Basics

舰艇电子技术基础

主　编　朱旭芳　钟　斌
副主编　马知远　潘　丽　吴文全　范　越

WUHAN UNIVERSITY PRESS
武汉大学出版社

图书在版编目(CIP)数据

舰艇电子技术基础/朱旭芳,钟斌主编. —武汉: 武汉大学出版社, 2017,4

海军工程大学涉外丛书

ISBN 978-7-307-18882-2

Ⅰ.舰…　Ⅱ.①朱…　②钟…　Ⅲ.军用船—模拟电路—电路分析—高等学校—教材　Ⅳ.①U674.7　②TN710

中国版本图书馆 CIP 数据核字(2016)第 288737 号

责任编辑:胡　艳　　责任校对:汪欣怡　　版式设计:马　佳

出版发行: **武汉大学出版社**　(430072　武昌　珞珈山)

(电子邮件: cbs22@whu.edu.cn　网址: www.wdp.com.cn)

印刷: 虎彩印艺股份有限公司

开本: 720×1000　1/16　印张:15　字数:352 千字　插页:1

版次: 2017 年 4 月第 1 版　2017 年 4 月第 1 次印刷

ISBN 978-7-307-18882-2　定价:30.00 元

前　言

“海军工程大学涉外丛书”所属的外训系列教材是外国留学生来校学习培训的专用教材，也可作为中国军校学员专业英语培训及双语教学的辅助教材。该系列教材的逐步推出和完善，是海军工程大学对外军事教育在教学理念、教学模式和条件建设上不断努力与探索的结果，必将更好地满足外国留学生的教学需求。其主要特点是：

1. 遵循海军工程大学《外训人才培养方案》和《外训课程标准》，以结构、功能、文化相结合为原则，以提高外国留学生的军事职业素养和专业综合技能为目标。

2. 内容的选择，强调突出各专业、各课程的知识体系及发展前沿，贴近外国军队建设和装备实际，并根据时代特点和外国留学生实际情况进行调整和补充，注重题材的丰富性和体裁的多样化。

3. 教材公开出版前，均邀请校内外的专家同行及外国留学生审阅、修改，并在多年的外训教学实践中进行锤炼和检验。

《舰艇电子技术基础》是“海军工程大学涉外丛书——外训系列教材”之一。全书共分十二章，系统而简要地介绍模拟和数字电子技术的基本组成、基本原理和基本分析设计方法。是一本有关舰艇和现代电子技术的基础读物。可以使学生了解电子技术的发展历史和现状，掌握电子技术的基本知识，开阔技术视野，培养职业素养，奠定下一步专业学习的基础。

本书由朱旭芳、钟斌负责纲目拟定和全书编写统稿，潘丽负责全书的文稿校对、插图和数字部分的编写工作，朱旭芳、马知远、吴文全负责模拟部分编写工作，范越负责习题和参考答案的编写工作。编写过程中，参考了大量国内外文献，吸收了国内外学者的最新研究成果。海军工程大学龚梅副教授为本书的英文审校付出了大量心血。武汉大学出版社为本书的出版提供了有力帮助。在此向各位专家、学者表示衷心的感谢。由于作者水平有限，书中难免存在疏漏和不当之处，敬请专家和读者提出宝贵意见。

编　者

2016年12月

目　　录

Introduction

We encounter electronics in our daily life in the form of telephones, radios, televisions, audio equipment, home appliances, computers and equipment for industrial control and automation. Electronics have become the stimuli for and an integral part of modern technological growth and development. The field of electronics deals with the design and applications of electronic devices.

History of Electronics

The age of electronics began with the invention of the first amplifying device, the triode vacuum tube, by Fleming in 1904. This invention was followed by the development of the solid-state point-contact diode (silicon) by Pickard in 1906, the first radio circuits from diodes and triodes between 1907 and 1927, the superheterodyne receiver by Armstrong in 1920, demonstration of television in 1925, and the field-effect device by Lilienfield in 1925, fm modulation by Armstrong in 1933, and radar in 1940.

The first electronics revolution began in 1947 with the invention of the silicon transistor by Bardeen, Bratain and Shockley at Bell Laboratories. Most of today's advanced electronic technologies are traceable to that invention, as modem microelectronics evolved over the years from the semiconductors. This revolution was followed by the first demonstration of color television in 1950 and the invention of the unipolar field effect transistor by Shockley in 1952.

The next breakthrough came in 1956, when Bell Laboratories developed the pnpn triggering transistor, also known as a thyristor or a silicon-controlled rectifier (SCR). The second electronics revolution began with the development of a commercial thyristor by General Electric Company in 1958. That was the beginning of a new era for applications of electronics in power processing or conditioning, called power electronics. Since then, many different types of power semiconductor devices and conversion techniques have been developed.The first integrated circuit (IC) was developed in 1958 simultaneously by Kilby at Texas Instruments and Noyce & Moore at Fairchild Semiconductor, marking the beginning of a new phase in the microelectronics revolution. This invention was followed by development of the first commercial IC operational amplifier, the μA709, by Fairchild Semiconductor in 1968; the 4004 microprocessor by Intel in 1971; the 8-bit microprocessor by Intel in 1972; and the gigabit memory chip by Intel in 1995. IC development continues today, in an effort to achieve higher density chips with lower power dissipation; historical levels of in integration in circuits are shown in Table 1.

Table 1

DATE	Degree of Integration	Number of Component per chip
1950s	Discrete components	1 to 2
1960s	Small-scale integration (SSI)	Fewer then 10^2
1966	Medium-scale integration (MSI)	From 10^2 to 10^3
1969	Large-scale integration (LSI)	From 10^3 to 10^4
1975	Very-large-scale integration (VLSI)	From 10^4 to 10^9
1990s	Ultra-large-scale integration (ULSI)	More than 10^9

Electronic Systems

An electronic system is an arrangement of electronic devices and components with a defined set of inputs and outputs. Using transistors (trans-resistors) as devices, it takes in information in the form of input signals (or simply inputs), performs operations on them, and then produces output signals (or outputs). Electronic systems may be categorized according to the type of application, such as communication system, medical electronics, instrumentation, control system, or computer system.

A block diagram of an fm radio receiver is shown in Figure 1 (a). The antenna acts the sensor. The input signal from the antenna is small, usually in the μV range; its amplitude and power level are then amplified by the electronic system before the signal is fed into the speaker. A block diagram of a temperature display instrument is shown in Figure 1 (b). The output drives the display instrument. The temperature sensor produces a small voltage, usually in millivolts per unit temperature rise above 0 degrees celsius (e.g., 1 mV/℃). Both systems take an input from a sensor, process it, and produce an output to drive an actuator.

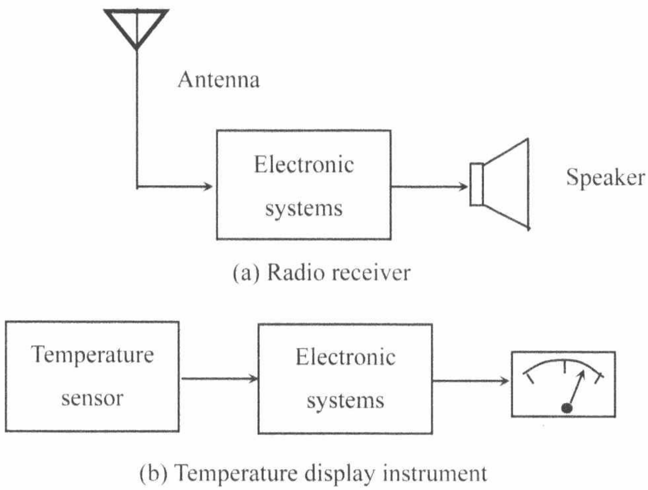

Figure 1 Electronic Systems

An electronic system must communicate with input and output devices. In general, the inputs and outputs are in the form of electrical signals. The input signals may be derived from the measurement of physical qualities such as temperature or liquid level, and the outputs may be used to vary other physical qualities such as those displays and heating elements. Electronic systems often use sensors to sense external input qualities and actuators to control external output qualities. Sensors and actuators are often called transducers. The loudspeaker is an example of a transducer that converts an electronic signal into sound.

Electronic Signals and Notation

Electronic signals can be separated into two categories: analog and digital. An analog signal has a continuous range of amplitudes over time, as shown in Figure 2(a). A digital signal assumes only discrete voltage values over time, as shown in Figure 2(b). A digital signal has only two values, representing binary logic state 1 (for high level) and binary logic state 0 (for low level). In order to accommodate variations in component values, temperature, and noise (or extraneous signals), logic sate 1 is usually assigned to any voltage between 2~5 V. Logic state 0 may be assigned to any voltage between 0~0.8 V.

The output signal of a sensor is usually of the analog type, and actuators often require analog input to produce the desired output. An analog signal can be converted to digital form and vice versa. The electronic circuits that perform these conversions are called analog-to-digital (A/D) and digital-to-analog (D/A) converters.

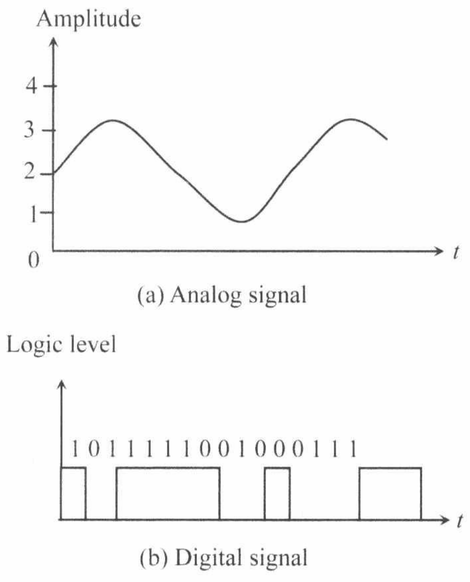

Figure 2 Electronic Signals

An analog signal is normally represented by a symbol with a subscript. The symbol and the subscript can be either uppercase or lowercase, according to the conventions shown in Table 2. For example, consider the circuit in Figure 3 (a), whose input consists of a dc voltage $V_{DC}=5$ V and an ac voltage $v_{ac}=2\sin\omega t$. The instantaneous voltages are shown in Figure 3 (b). The definitions of voltage and current symbols are as follows:

(1) V_{DC}, I_{DC} are dc values: uppercase variables and uppercase subscripts.

$$V_{DC}=5\text{V}$$

$$I_{DC}=\frac{V_{DC}}{R_L}=5\text{ mA}$$

(2) v_{ab}, i_a are instantaneous ac values: lowercase variables and lowercase subscripts.

$$v_{ab}=v_{ac}=2\sin\omega t$$

$$i_a=2\sin\omega t\text{ mA}\quad(\text{for } R_L=1\text{ k}\Omega)$$

(3) v_{AB}, i_A are total instantaneous values: lowercase variables and uppercase sub-scripts.

$$v_{AB}=V_{DC}+v_{ab}=5+2\sin\omega t$$

$$i_A=I_{DC}+i_a=5\text{ mA}+2\sin\omega t\text{ mA}\quad(\text{for } R_L=1\text{ k}\Omega)$$

(4) V_{ab}, I_a are total magnitude values: upper variables and lowercase subscripts.

$$V_{ab}=\sqrt{5^2+(\sqrt{2})^2}=5.2\text{V}$$

$$I_a=\sqrt{5^2+(\sqrt{2})^2}=5.2\text{mA}$$

Table 2

Definition	Quantity	Subscript	Example
dc value of the signal	Uppercase	Uppercase	V_D
ac value of the signal	Lowercase	Lowercase	v_d
Total instantaneous value of the signal (dc and ac)	Lowercase	Uppercase	v_D
Complex variable, phasor, or rms value of the signal	Uppercase	Lowercase	V_d

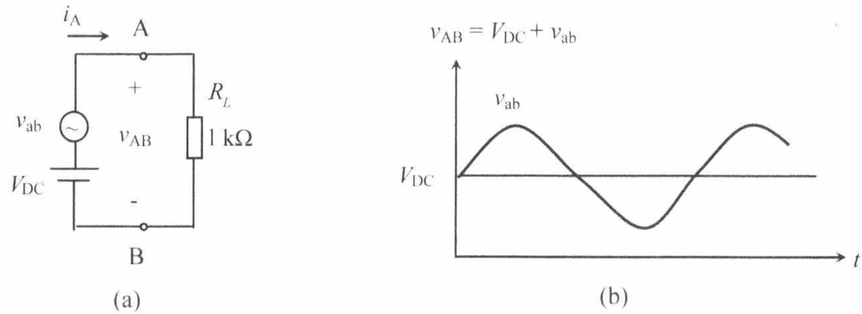

Figure 3 Notation for Electronic Signals

Chapter 1

Diodes and Applications

1.1 Introduction

A diode is a two-terminal semiconductor device. It offers a low resistance on the order of mΩ in one direction and a high resistance on the order of GΩ in the other direction. Thus a diode permits an easy current flow in only one direction. The diode is a simplest electronic device, and a basic building block for many electronic circuits and systems. In this chapter, we will discuss the characteristics of diodes.

The diode exhibits a nonlinear relation between the voltage across its terminals and the current through it. However, the analysis of the diode can be greatly simplified with the assumption of an ideal characteristic. The results of this simplified analysis are useful in understanding the operation of diode circuits and are acceptable in many practical cases, especially at the initial stage of design and analysis. If more accurate results are required, linear circuit models representing the nonlinear characteristic of diodes can be used. These models are commonly used in evaluating the performance of diode circuits. If better accuracy is required, however, computer-aided modeling and simulation are normally used.

1.2 Ideal Diodes

The symbol for a semiconductor diode is shown in Figure 1.2.1(a). Its two terminals are the anode and the cathode, respectively. If the anode voltage is held positive with respect to the cathode terminal, the diode conducts and offers a small forward resistance. The diode is then said to be forward biased, and it behaves as a short circuit, as shown in Figure 1.2.1(b). If the anode voltage is kept negative with respect to the cathode terminal, the diode offers a high resistance. The diode is then said to be reverse biased and it behaves as an open circuit, as shown in Figure 1.2.1(c). Thus an ideal diode will offer zero resistance and zero voltage drop in the forward direction. In the reverse direction, it will offer infinite resistance and allow zero current.

An ideal diode acts as a short circuit in the forward region of conduction ($v_D = 0$) and as an open circuit in the reverse region of conduction ($i_D = 0$). The *v-i* characteristic of an ideal diode is shown in Figure 1.2.1 (d). As the forward voltage accross the diode tends to be greater than zero, the forward current through it tends to infinite. In practice, however, a diode is connected to other circuit elements, such as resistances, and its forward current is limited to a known value.

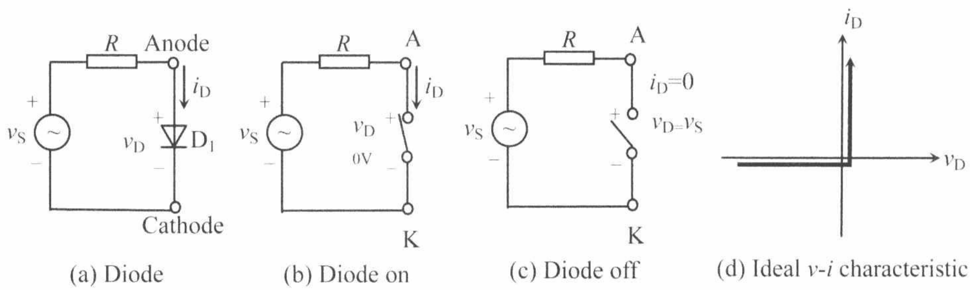

Figure 1.2.1 Characteristic of An Ideal Diode

1.3 Practical Diodes

The characteristic of a practical diode that distinguishes it from an ideal one is that the practical diode experiences a finite voltage drop when it conducts. This drop is typically in the range of 0.5~0.7V. If the input voltage to a diode circuit is high enough; the drop is too small and can thus be ignored. The voltage drop may, however, cause a significant error in electronic circuits, and the diode characteristic should be taken into account in evaluating the performance of diode circuits. In order to understand the characteristic of a practical diode, we need to understand its physical operation.