高等学校教材

自动化专业英语教程

Specified English for Automation

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陈在平
孙进生 副主编

机械工业出版社

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本书是针对高等工科院校自动化专业科技英语阅读课程的需要而编写的，内容包括电力电子技术、控制理论、计算机控制技术、电力传动、过程控制、供电技术及智能大厦等六部分，涵盖了自动化专业各个发展方向，并力求反映最新内容。每篇文章后附有词汇表和注解，并配有 29 篇英语翻译及应用文知识，便于读者学习并掌握专业词汇和翻译技能。本书可作为自动化专业本科生及研究生专业英语课程的教材，也可供有关工程技术人员参考。

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序

人类社会的"全球化"加速了中国面向世界的国际化进程。中国的改革和对外开放，使中国的经济、科技、教育、文化日益与世界文明接轨，日益国际化。这就需要培养一大批具有开阔视野、较强交际能力、训练有素的国际型人才，只有熟练掌握外语才有可能在国际舞台上施展才能。

当代科学技术的急速变化，使得"日新月异"不仅是个形容文字，更是活生生的事实。世界正处于前所未有的变化中，中国正面临着前所未有的发展机遇。国家之间的竞争常常是高科技的竞争，作为发展中国家的中国要奋起直追，要借鉴当今世界的最新成就来富国强民，通过译介引进这些成就就显得十分重要。

《自动化专业英语教程》一书是作者根据多年专业英语课程的教学实践，参照国家教委制定的有关专业英语教学要求编写的。在选材上重视先进性，课文大部分选自欧美国家相关专业的教学参考书；在编排上力求系统性，较好地贯穿了自动化专业的全部专业课程。整个教程的编写力图面向21世纪，选编了许多新知识，如电力电子技术、模糊控制、神经网络、PLC、微机控制技术、过程自动化、楼宇自动化与智能大厦等，使这门课程不仅是对专业课程的总结，而且又是一种补充。本书另一特色是增加了专业英语知识以加强对学生专业英语技能的培养，并选编和介绍了科技写作、广告、说明书、信函、合同与协议等，这有助于培养学生综合能力，提高全面素质，使得本书内容更加丰富。本书既是一本专业教材，又是一本专业参考书。

目前，许多高校自动化专业相继开设了专业英语课程，然而缺少一本适应我国高校自动化专业教学的专业英语教材。这本书的出版，无疑为自动化专业英语教学提供了一本好教材。由衷地感谢本书的作者，对他们的努力和杰出工作表示钦佩。希望这本书为自动化专业以及相关专业的专业英语教学起到推动作用，为面向 21 世纪教学内容和课程体系改革及人才模式的培养起到积极作用。

孙鹤旭

1998年5月18日

前　言

本书是根据作者多年从事高等工科院校自动化专业本科生及研究生专业英语课程的教学实践，并参照国家教委制定的相关规定而编写的。本书可以作为高等工科院校自动化专业本专科生或研究生的专业英语学习教材，也可供从事相关专业技术工作的工程人员作为参考资料。

根据国家教委要求，大学生在经过基础英语的学习后，基本上已掌握了英语中的常用语法和四千以上的词汇量，具备了较扎实的外语基础。进入三年级后，随着专业课的进一步学习，学生的专业知识技能也开始逐步加强。具备了以上两个条件后，应进行专业外语的训练，在保证 20 万字以上阅读量的基础上，对本专业外文资料的阅读达到基本的要求。随着专业技术的迅速发展和国际间科学技术交流增加，专业英语作为专业基础技能越来越显示出其重要性，因而受到广泛关注。

长期以来自动化专业一直缺少一本较为统一的、覆盖面较广的专业英语教材，这显然是难以满足教学需要的。因此，结合国家教委最新颁布的专业目录，我们联合津、冀两地五所工科高校编写了这本教材——《自动化专业英语教程》。

全书共包括电力电子技术、控制理论、计算机控制技术、电力传动、过程控制、供电技术及智能大厦等六个部分共 29 个单元（每单元包括 2 篇文章和 1 篇专业英语知识）。各校可根据教学需要选学其中的相关内容。

本书由王宏文担任主编，陈在平、孙进生担任副主编。书中 Part1 的 Unit1 由綦建编写，Part1 的 Unit2、3 和 Part2 的 Unit6 由王萍编写，Part1 的 Unit4~6、Part2 的 Unit7、8 和 Part3 的 Unit3B 由陈在平编写，Part2 的 Unit1~5 由李练兵编写，Part3 的 Unit4 由李练兵和陈志军编写，Part3 的 Unit1、2、3A、5 由陈志军和薛忠辉编写，Part4 由孙进生编写，Part5 由耿昕编写，Part6 由王宏文编写，Part1、2、3、6、Part4 中 Unit3 和 part5 中 Unit4 的专外知识介绍由刘作军编写，Part4 中 Unit1、2、4 的专外知识介绍由暴永辉编写，Part5 中 Unit1、2、3 的专外知识介绍由林燕编写，河北工业大学王宏文副教授对全书进行了总编和修改更正，李练兵和刘作军负责了全书的计算机编辑和整理工作。河北工业大学杨鹏副教授、天津理工学院魏克新教授担任了主审，为本书提出了大量宝贵意见和建议。河北理工学院林行辛教授、河北科技大学的刘永强以及陈曦等同志对本书的编写也给予了大力协助，孙鹤旭教授在为本书的出版提供大力帮助的同时还为本书题写了序言，在此表示由衷的感谢。

由于编写人员水平有限，书中难免不足之处，欢迎大家予以批评指正。

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编　者

1998 年 5 月

目　　录

PART 1

Power Electronics Technology

UNIT 1

A: Electrical Networks

An *electrical circuit or network* is composed of elements such as resistors, inductors, and capacitors connected together in some manner. If the network contains no energy sources, such as batteries or electrical generators, it is known as a *passive network*. On the other hand, if one or more energy sources are present, the resultant combination is an *active network*. In studying the behavior of an electrical network, we are interested in determining the voltages and currents that exist within the circuit. Since a network is composed of passive circuit elements, we must first define the electrical characteristics of these elements.

In the case of a resistor, the voltage-current relationship is given by Ohm's law, which states that the voltage across the resistor is equal to the current through the resistor multiplied by the value of the resistance.[1] Mathematically, this is expressed as

$$u = iR \tag{1-1A-1}$$

where u= voltage, V; i = current, A; R = resistance, Ω.

The voltage across a pure inductor is defined by Faraday's law, which states that the voltage across the inductor is proportional to the rate of change with time of the current through the inductor. Thus we have

$$u = L\frac{\mathrm{d}i}{\mathrm{d}t} \tag{1-1A-2}$$

where $\mathrm{d}i/\mathrm{d}t$ = rate of change of current, A/s; L = inductance, H.

The voltage developed across a capacitor is proportional to the electric charge q accumulating on the plates of the capacitor. Since the accumulation of charge may be expressed as the summation, or integral, of the charge increments $\mathrm{d}q$, we have the equation

$$u = \frac{1}{C}\int \mathrm{d}q \tag{1-1A-3}$$

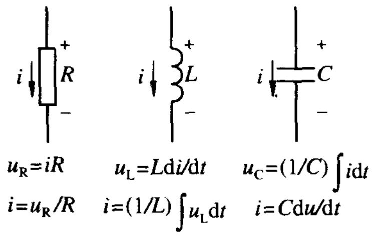
Where the capacitance C is the proportionality constant relating voltage and charge. By definition, current equals the rate of change of charge with time and is express as $i = \mathrm{d}q/\mathrm{d}t$. Thus an increment of charge $\mathrm{d}q$ is equal to the current multiplied by the corresponding time increment, or $\mathrm{d}q = i\,\mathrm{d}t$. Eq.

(1-1A-3) may then be written as

$$u = \frac{1}{C}\int i\mathrm{d}t \qquad (1\text{-}1A\text{-}4)$$

where C = capacitance, F.

A summary of Eqs. (1-1A-1), (1-1A-2) and (1-1A-4) for the three forms of passive circuit elements is given in Fig. 1-1A-1. Note that conventional current flow is used; hence the current in each element is shown in the direction of decreasing voltage.



a) Resistor b) Inductor c) Capcitor

Fig. 1-1A-1 Passive circuit elements

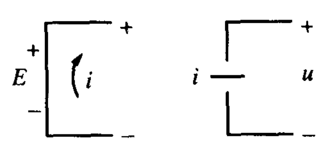
Active electrical devices involve the conversion of energy to electrical form. For example, the electrical energy in a battery is derived from its stored chemical energy. The electrical energy of a generator is a result of the mechanical energy of the rotating armature.

Active electrical elements occur in two basic forms: *voltage sources* and *current sources*. In their ideal form, voltage sources generate a constant voltage independent of the current drawn from the source. The aforementioned battery and generator are regarded as voltage sources since their voltage is essentially constant with load. On the other hand, current sources produce a current whose magnitude is independent of the load connected to the source. Although current sources are not as familiar in practice, the concept does find wide use in representing an amplifying device, such as the transistor, by means of an equivalent electrical circuit. Symbolic representations of voltage and current sources are shown in Fig. 1-1A-2.

A common method of analyzing an electrical network is mesh or loop analysis. The fundamental law that is applied in this method is Kirchhoff's first law, which states that the algebraic sum of the voltages around a closed loop is 0, or, in any closed loop, the sum of the voltage rises must equal the sum of the voltage drops. Mesh analysis consists of assuming that currents —— termed loop currents —— flow in each loop of a network, algebraically summing the voltage drops around each loop, and setting each sum equal to 0.

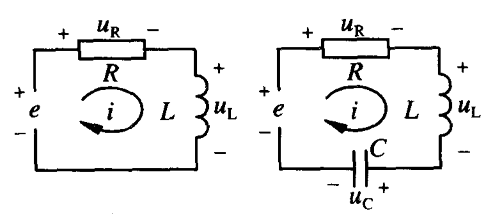
Consider the circuit shown in Fig. 1-1A-3a, which consists of an inductor and resistor connected in series to a voltage source e. Assuming a loop current i, the voltage drops summed around the loop are

$$-e + u_R + u_L = 0 \qquad (1\text{-}1A\text{-}5)$$



a) Voltage source b) Current source

Fig. 1-1A-2 Voltage source and current source



a) b)

Fig. 1-1A-3 Series circuits containing R, L and C

The input voltage is summed negatively since, in the direction of assumed current, it represents an increase in voltage. The drop across each passive element is positive since the current is in the direction of the developed voltage.

Using the equations for the voltage drops in a resistor and inductor, we have

$$L\frac{\mathrm{d}i}{\mathrm{d}t}+Ri=e \tag{1-1A-6}$$

Eq. (1-1A-6) is the differential equation for the current in the circuit.

It may be that the inductor voltage rather than the current is the variable of interest in the circuit.[2] As noted in Fig. 1-1A-1, $i=\frac{1}{L}\int u_{\mathrm{L}}\mathrm{d}t$. Substituting this integral for i in Eq. (1-1A-6) gives

$$u_{\mathrm{L}}+\frac{R}{L}\int u_{\mathrm{L}}\mathrm{d}t=e \tag{1-1A-7}$$

After differentiation with respect to time, Eq. (1-1A-7) becomes

$$\frac{\mathrm{d}u_{\mathrm{L}}}{\mathrm{d}t}+\frac{R}{L}u_{\mathrm{L}}=\frac{\mathrm{d}e}{\mathrm{d}t} \tag{1-1A-8}$$

which is the differential equation for the inductor voltage.

Fig. 1-1A-3b shows a series circuit containing a resistor, inductor, and capacitor. Following the mesh-analysis method outlined above, the circuit equation is

$$L\frac{\mathrm{d}i}{\mathrm{d}t}+Ri+\frac{1}{C}\int i\mathrm{d}t=e \tag{1-1A-9}$$

Recalling that current i = dq/dt, a substitution of this variable may be made to eliminate the integral from the equation. The result is the second-order differential equation

$$L\frac{\mathrm{d}^2q}{\mathrm{d}t^2}+R\frac{\mathrm{d}q}{\mathrm{d}t}+\frac{q}{C}=e$$

WORDS AND TERMS

network *n.* 网络，电路
identify *v.* 识别，认出，视为同一，一致
resistor *n.* 电阻器
inductor *n.* 电感器
capacitor *n.* 电容器
passive network 无源网络
active network 有源网络
characteristic *adj. n.* 特性(的)；特性曲线
Ohm *n.* 欧姆
Faraday *n.* 法拉第
electric charge 电荷
integral *n.* 积分
increment *n.* 增量
armature *n.* 电枢
aforementioned *adj.* 上述的；前面提到的
represent *v.* 代表；表示；阐明
amplify *v.* 放大
symbolic *adj.* 符号的；记号的
mesh *n.* 网孔
loop current 回路电流
voltage drop 电压降
in series 串联
variable *n.* 变量
differential *adj. n.* 微分的；微分
outline *n. v.* (画)轮廓；提出……的要点
eliminate *v.* 消除；对消；
parameter *n.* 参数

NOTES

[1] In the case of a resistor, the voltage-current relationship is given by Ohm's law, which states that the voltage across the resistor is equal to the current through the resistor multiplied by the value of the resistance.

就电阻来说，电压-电流的关系由欧姆定律决定，欧姆定律指出：电阻两端的电压等于电阻上流过的电流乘以电阻值。

in the case of：就……来说，就……而论

in case (of)：假如；万一；在……的情况下

in that case：那么，既然是那样

in this case：既然是这样

in any case：无论如何，总之

in all case：就一切情况而论

[2] It may be that the inductor voltage rather than the current is the variable of interest in the circuit.

或许在电路中，人们感兴趣的变量是电感电压而不是电感电流。

M rather than N：是 M 而不是 N

of interest：有价值的；使人感兴趣的；有意义的

B: Three-phase Circuits

A three-phase circuit is merely a combination of three single-phase circuits. Because of this fact, current, voltage, and power relations of balanced three-phase circuits may be studied by the application of single-phase rules to the component parts of the three-phase circuit. Viewed in this light, it will be found that the analysis of three-phase circuits is little more difficult than that of single-phase circuits.[1]

Reasons for Use of Three-phase Circuits

In a single-phase circuit, the power is of a pulsating nature. At unity power factor, the power in a single-phase circuit is zero twice each cycle.[2] When the power factor is less than unity, the power is negative during parts of each cycle. Although the power supplied to each of the three phases of a three-phase circuit is pulsating, it may be proved that the total three-phase power supplied a balanced three-phase circuit is constant. Because of this, the characteristics of three-phase apparatus, in general, are superior to those of similar single-phase apparatus.

Three-phase machinery and control equipment are smaller, lighter in weight, and more efficient than single-phase equipment of the same rated capacity. In addition to the above-mentioned advantages offered by a three-phase system, the distribution of three-phase power requires only three-fourths as much line copper as does the single-phase distribution of the same amount of power.

Generation of Three-phase Voltages

A three-phase electric circuit is energized by three alternating emfs of the same frequency and differing in time phase by 120 electrical degrees. Three such sine-wave emfs are shown in Fig. 1-1B-1. These emfs are generated in three separate sets of armature coils in an ac generator. These three sets of coils are mounted 120 electrical degrees apart on the generator armature. The coil ends may all be brought out of the generator to form three separate single-phase circuits. However, the coils are ordinarily interconnected either internally or externally to form a three wire or four-wire three-phase system.

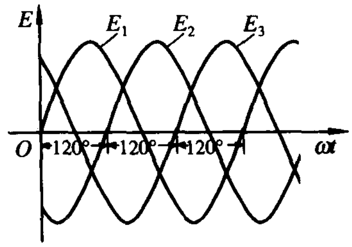


Fig. 1-1B-1 Three sine-wave emfs differing in phase by 120 electrical degrees such as are used for energizing a three-phase circuit

There are two ways of connecting the coils of three-phase generators, and in general, there are two ways of connecting devices of any sort to a three-phase circuit. These are the *wye-connection* and the *delta-connection*. Most generators are wye-connected, but loads may be either wye-connected or delta-connected.

Voltage Relations in a Wye-connected Generator

Fig. 1-1B-2a represents the three coils or phase windings of a generator. These windings are so spaced on the armature surface that the emfs generated in them are 120° apart in time phase. Each coil ends lettered S and F (start and finish). In Fig. 1-1B-2a, all the coil ends marked S are connected to a common point N, called the neutral, and the three coil ends marked F are brought

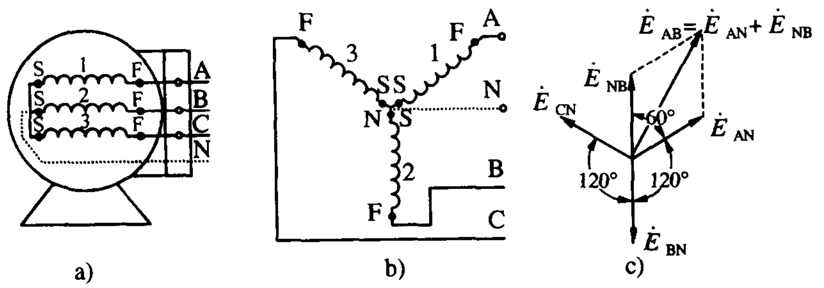


Fig. 1-1B-2 a) Connection of the phase windings in a wye-connection generator

b) Conventional diagram of a wye connection

c) Phasor diagram showing the relation between phase and line voltages

out to the line terminals A, B, and C to form a three-wire three-phase supply. This type of connection is called the Wye-connection. Often the neutral connection is brought out to the terminal board, as shown by the dotted line in Fig. 1-1B-2a, to form a four-wire three-phase system.

The voltages generated in each phase of an ac generator are called the *phase voltages* (symbol E_p). If the neutral connection is brought out of the generator, the voltage from any one of the line terminals A, B, or C to the neutral connection N is a phase voltage. The voltage between any two of the three line terminals A, B, or C is called line-to-line voltage or, simply, a *line voltage* (symbol E_L).

The order in which the three voltages of a three-phase system succeed one another is called the phase sequence or the phase rotation of the voltages. This is determined by the direction of rotation of the generator but maybe reversed outside the generator by interchanging any two of the three line wires (not a line wire and a neutral wire).

It is helpful when drawing circuit diagrams of wye connection to arrange the three phases in the shape of a Y as shown in Fig. 1-1B-2b. Note that the circuit of Fig. 1-1B-2b is exactly the same as that of Fig. 1-1B-2a, with the S end of each coil connected to the neutral point and the F end brought out to the Terminal in each case. After a circuit diagram has been drawn with all intersections lettered, a phasor diagram may be drawn as in Fig. 1-1B-2c. The phasor diagram shows the three phase voltages $\dot{E}_{AN}$, $\dot{E}_{BN}$, and $\dot{E}_{CN}$ which are 120° apart.

It should be noted in Fig. 1-1B-2 that each phasor is lettered with two subscripts. The two letters indicate the two points between which the voltage exists, and the order of the letters indicates the relative polarity of the voltage during its positive half-cycle. For example, the symbol $\dot{E}_{AN}$ indicates a voltage between the points A and N with the point A being positive with respect to point N during its positive half-cycle. In the phasor diagram shown, it has been assumed that the generator terminals were positive with respect to the neutral during the positive half-cycle. Since the voltage reverses every half-cycle, either polarity may be assumed if this polarity is assumed consistently for all three phases. It should be noted that if the polarity of point A with respect to N ($\dot{E}_{AN}$) is assumed for the positive half-cycle, then $\dot{E}_{NA}$ when used in the same phasor diagram should be drawn opposite to, or 180° out of phase with, $\dot{E}_{AN}$.[3]

The voltage between any two line terminals of wye-connected generator is the difference between the potentials of these two terminals with respect to the neutral. For example, the line voltage $\dot{E}_{AB}$ is equal to the voltage A with respect to neutral ($\dot{E}_{AN}$) minus the voltage B with respect to neutral ($\dot{E}_{BN}$). To subtract $\dot{E}_{BN}$ from $\dot{E}_{AN}$, it is necessary to reverse $\dot{E}_{BN}$ and add this phase to $\dot{E}_{AN}$. The two phasors $\dot{E}_{AN}$ and $\dot{E}_{NB}$ are equal in length and are 60° apart, as shown in Fig. 1-1B-2c. It may be shown graphically or proved by geometry that $\dot{E}_{AB}$ is equal to 1.73, multiplied by the value of either $\dot{E}_{AN}$ or $\dot{E}_{NB}$. The graphical construction is shown in the phasor diagram. Therefore, in a balanced wye connection

$$E_L = 1.73E_P$$

Current Relations in a Wye-connected Generator

The current flowing out to the line wires from the generator terminals A, B, and C (Fig. 1-1B-2) must flow from the neutral point N, out through the generator coils. Thus, the current each line wire (I_L) must equal the current in the phase (I_P) to which it is connected. In a wye connection

$$I_L = I_P$$

WORDS AND TERMS

pulsate *vi.* 脉动；跳动；振动
armature *n.* 电枢；衔铁；加固；加强
apparatus *n.* 一套仪器；装置
coil *n. v.* (绕）线圈；绕组；盘绕
rated *adj.* 额定的；设计的；适用的
generator *n.* 发生器；发电机
distribution *n.* 分配；分布；配电
interconnect *v.* 互相连接；
emf（electromotive force）电动势
wye *n.* Y 形联结；星形联结；三通
delta *n.* 希腊字母Δ（δ）；三角形（物）
geometry *n.* 几何学；几何形状
windings *adj., n.* 缠绕的；线圈；绕组；
polarity *n.* 极性
neutral *adj. n.* 中性的；中性线
subscript *n.* 下标；角注；索引
succeed *v.* 继……之后；接替
intersection *n.* 相交；逻辑乘法
phase sequence 相序
reverse *v. n. adj.* 反转；变换极性

NOTES

[1] Viewed in this light, it will be found that the analysis of three-phase circuits is little more difficult than that of single-phase circuits.

这样看来，三相电路的分析比单相电路的分析难不了多少。

viewed in this light: 从这个意义上来看

that: 代 analysis。

[2] At unity power factor the power in a single-phase circuit is zero twice each cycle.

在功率因数为 1 时，单相电路里的功率值每个周波有两次为零。

twice each cycle: 每个周波有两次（为零）。twice 和 each cycle 都作状语。

[3] It should be noted that if the polarity of point A with respect to N ($\dot{E}_{AN}$) is assumed for the positive half-cycle, then $\dot{E}_{AN}$ when used in the same phasor diagram should be drawn opposite to, or 180° out of phase with, $\dot{E}_{AN}$.

应该注意，如果把 A 点相对于 N 的极性（$\dot{E}_{AN}$）定为正半周，那么 $\dot{E}_{AN}$ 在用于同一相量图中时就应该画得同 $\dot{E}_{AN}$ 相反，即相位差为 180°。

with respect to: 相对于；关于

C：专业英语(Specified English)概述

根据国家教委要求，大学生在经过基础英语的学习后，基本上已掌握了英语中的常用语法和 4000 以上的词汇量，具备了较扎实的英语基础。进入三年级后，随着专业课的进一步学习，学生的专业知识技能也开始逐步加强。具备了以上两个条件后，应进行专业英语的训练，在保证 20 万字以上阅读量的基础上，对本专业英文资料的阅读应达到基本的要求。换而言之，掌握专业英语技能是大学基础英语学习的主要目的之一，是一种素质上的提高，

直接关系到学生的求职和毕业后的工作能力。

专业英语的重要性体现在很多方面：大到日益广泛的国际间科学技术交流，小到对产品说明书的翻译。而近几年普及的 Internet 网为工程技术人员提供了更为巨大的专业信息量，作为网络上主要语言的英语则对资料查询者提出了更高的要求。

尽管很多人在此之前已经进行了至少八年的基础英语学习，但专业英语的学习仍是很必要的。首先，专业英语在词义上具有不同于基础英语的特点和含义。如下例：

If a mouse is installed in a computer, then the available memory space for user will reduce.

错误译法：如果让老鼠在计算机里筑窝，那么使用者的记忆空间就会减少。

专业译法：如果计算机安装了鼠标，则用户可利用的内存空间就会减少。

Connect the black pigtail with the dog-house.

错误译法：把黑色的猪尾巴系在狗窝上。

专业译法：将黑色的引出线接在高频高压电源屏蔽罩上。

通过以上的例子，我们不难认识到专业词汇的一些特点，同一个词在日常生活中、在不同的专业中可能会有截然不同的含义，单靠日常用语进行望文生意的判断不仅会闹笑话，还有可能出事故；其次，外文科技文章在结构上也具有很多自身的特点，如长句多，被动语态多，大量的名词化结构等，这都给对原文的理解和翻译带来了基础英语中所难以解决的困难。再者，专业英语对听说读写译的侧重点不同，其最主要的要求在于“读”和“译”，也就是通过大量的阅读对外文资料进行正确的理解和翻译(interpretation & translation)，在读和译的基础上，对听、说、写进行必要的训练；此外，专业外文资料由于涉及许多科技内容而往往极为复杂难以理解，加之这类文章的篇幅通常很长，所以只有经过一定的专业外语训练，才能完成从基础英语到专业英语的过渡，达到英语学以致用的最终目的。

专业翻译是指把科技文章由原作语言(source language)用译文语言(target language)忠实、准确、严谨、通顺、完整地再现出来的一种语言活动，它要求翻译者在具有一定专业基础知识(The knowledge of your major)和英语技能的前提下，借助于一本合适的英汉科技字典(A dictionary for science and technology)来完成整个翻译过程。专业翻译直接应用于科技和工程，因而对翻译的质量具有极高的要求，翻译上的失之毫厘，工程中就有可能差之千里，造成巨大的损失。例如这样一个标志牌：

Control Center. Smoking Free.

它的意思是“控制中心，严禁吸烟”，free 在这里作“免除……的”讲，而如果理解为“随便的，自由的”就会产生完全相反的效果。

UNIT 2

A: The Operational Amplifier

One problem with electronic devices corresponding to the generalized amplifiers is that the gains, A_U or A_I, depend upon internal properties of the two-port system (μ, β, R_i, R_o, etc.).[1] This makes design difficult since these parameters usually vary from device to device, as well as with temperature. The operational amplifier, or Op-Amp, is designed to minimize this dependence and to maximize the ease of design. An Op-Amp is an integrated circuit that has many component parts such as resistors and transistors built into the device. At this point we will make no attempt to describe these inner workings.

A totally general analysis of the Op-Amp is beyond the scope of some texts. We will instead study one example in detail, then present the two Op-Amp laws and show how they can be used for analysis in many practical circuit applications. These two principles allow one to design many circuits without a detailed understanding of the device physics. Hence, Op-Amps are quite useful for researchers in a variety of technical fields who need to build simple amplifiers but do not want to design at the transistor level. In the texts of electrical circuits and electronics they will also show how to build simple filter circuits using Op-Amps. The transistor amplifiers, which are the building blocks from which Op-Amp integrated circuits are constructed, will be discussed.

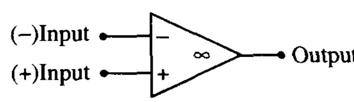


Fig. 1-2A-1 Operational amplifier

The symbol used for an ideal Op-Amp is shown in Fig.1-2A-1. Only three connections are shown: the positive and negative inputs, and the output. Not shown are other connections necessary to run the Op-Amp such as its attachments to power supplies and to ground potential. The latter connections are necessary to use the Op-Amp in a practical circuit but are not necessary when considering the ideal Op-Amp applications we study in this chapter. The voltages at the two inputs and the output will be represented by the symbols U^+, U^-, and U_o. Each is measured with respect to ground potential. Operational amplifiers are differential devices. By this we mean that the output voltage with respect to ground is given by the expression

$$U_o = A(U^+ - U^-) \tag{1-2A-1}$$

where A is the gain of the Op-Amp and U^+ and U^- the voltages at inputs. In other words, the output voltage is A times the difference in potential between the two inputs.

Integrated circuit technology allows construction of many amplifier circuits on a single composite "chip" of semiconductor material. One key to the success of an operational amplifier is the "cascading" of a number of transistor amplifiers to create a very large total gain. That is, the number A in Eq. (1-2A-1) can be on the order of 100,000 or more. (For example, cascading of five transistor amplifiers, each with a gain of 10, would yield this value for A.) A second important