21世纪全国高等院校自动化系列实用规划教材

自动化专业英语

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内 容 简 介

本书具有选材广泛、内容丰富、专业性和实用性强的特点，可使读者通过较短时间的学习，显著提高专业英语词汇量、专业文献的阅读和翻译能力。

全书共有课文 25 篇，主要包括模拟和数字电子技术、自动控制理论基础、过程控制、传感器、PLC 和单片机等方面的内容。每课都由课文、生词表、注释、翻译技巧、英译中和中译英的练习、阅读材料和课文参考翻译组成，同时还有内容丰富的附录，具有较强的知识延伸性。

本书可作为自动化、电子信息工程、电气工程、机电一体化及其他相关专业的教材，也可用于成人教育及职工培训，同时可供电子、电气、自动化和机电专业的工程技术人员作为参考。

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总　　序

我们所处的时代被称为信息时代。信息科学与技术的迅速发展和广泛应用，深深地改变着人类生产、生活的各个方面。人类社会生产力发展和人们生活质量的提高越来越得益于和依赖于信息科学与技术的发展。自动化科学与技术涉及到信息的检测、分析、处理、控制和应用等各个方面，是信息科学与技术领域的重要组成部分。在我国经济建设的进程中，工业化是不可逾越的发展阶段。面对全面建设小康社会的发展目标，党和国家提出走新型工业化道路的战略决策，这是一条我国当代工业化进程的必由之路。实现新型工业化，就是要坚持走科技含量高、经济效益好、资源消耗低、环境污染少、人力资源优势得到充分发挥的可持续发展的科学发展之路。在这个过程中，自动化科学与技术起着不可替代的重要作用，高等学校的自动化学科肩负着人才培养和科学研究的光荣的历史使命。

我国高等教育中工科在校大学生数占在校大学生总数的35%～40%，其中自动化类的学生是工科各专业中学生人数最多的专业之一。在我国高等教育已走进大众化阶段的今天，人才培养模式多样化已成为必然的趋势，其中应用型人才是我国经济建设和社会发展需求最多的一大类人才。为了促进自动化领域应用型人才培养，发挥院校之间相互合作的优势，北京大学出版社组织了此套《21世纪全国高等院校自动化系列实用规划教材》。

参加这一系列教材编写的基本上都是来自地方工科院校自动化学科的专家学者，由此确定了教材的使用范围，也为“实用教材”的定位找到了落脚点。本系列教材具有如下特点：

(1)　注重实用性。地方工科院校的人才培养规格大多定位在高级应用型，对这一大类人才的培养要注重面向工程实践，培养学生理论联系实际、解决实际问题的能力。从这一教学原则出发，本系列教材注重实用性，注意引用工程中的实例，培养学生的工程意识和工程应用能力，因此将更适合地方工科院校的教学要求。

(2)　体现新颖性。更新教材内容，跟进时代，加入一些新的先进实用的知识，同时淘汰一些陈旧过时的内容。

(3)　院校间合作交流的成果。每一本教材都有几所院校的教师参加编写。北大出版社事先在西安市和长春市召开了编写计划会和审纲会，来自各院校的教师比较充分地交流了情况，在相互借鉴、取长补短的基础上，形成了编写大纲，确定了编写原则。因此，这一系列教材可以反映出各参编院校一些好的经验和做法。

(4)　这一系列教材几乎涵盖了自动化类专业从技术基础课到专业课的各门课程，到目前为止，列入计划的已有30多门，教材门数多，参与的院校多，参加编写人员多。

地方工科院校是我国高等院校中比例最大的一部分。本系列教材面向地方工科院校自动化类专业教学之用，将拥有众多的读者。教材专家编审委员会深感教材的编写质量对教学质量的重要性，在审纲会上强调了“质量第一，明确责任，统筹兼顾，严格把关”的原则，要求各位主编加强协调，认真负责，努力保证和提高教材质量。各位主编和编者也将尽职尽责，密切合作，努力使自己的作品受到读者的认可和欢迎。尽管如此，由于院校之间、编者之间的差异性，教材中还是难免会出现一些问题和不足，欢迎选用本系列教材的教师、学生提出批评和建议。

张德江

2006 年 1 月

前　　言

电子信息与自动化是目前国际国内发展最为迅速、技术更新最为活跃的工程领域之一。面对日趋激烈的国际化竞争，学生在学习阶段就应打下坚实的专业基础。而专业英语的阅读、翻译和写作能力是电子信息与控制工程专业毕业生所应具备的一项重要能力。在我国，先进技术和设备的引进，外向型经济的发展，使得对具有专业英语能力的人才的需求激增。本教材就是为了满足这一需求而编写的。

本书课文的选材尽量兼顾本学科的各个领域，以扩充学生的专业词汇量、提高学生专业英语的阅读和写作能力、扩展和深化学生对本学科关键技术的认识、培养具备国际竞争力的技术人才为目的。为了保证内容的先进性和实用性，本书中的文章均选自国外电子信息各个领域的最新教材、专著或国际著名公司网站提供的技术应用文章。在具体内容的遴选上，尽量保证学生利用既有专业知识理解课文的内容，并使学生通过学习加深和扩展相关专业知识。课文的内容既对专业基础课和专业课进行必要的重复，又有所拓宽和延伸。全书注重提高学生阅读专业书刊、阅读和翻译引进设备技术文件、用英语撰写专业论文等方面的能力。每个单元分课文、生词和短语、注释、科技英语翻译知识、英汉互译练习、阅读材料和课文参考翻译等部分。其中，课文侧重展示本领域的关键技术，选取了那些能够扩展、深化学生对本学科认识的内容。课文注释旨在解决课文中英语语言难点和专业知识难点。练习题紧紧围绕课文内容和翻译知识，便于加深对课文的领会。科技英语翻译部分比较系统地介绍了科技英语翻译的一般方法和技巧。阅读材料则着力介绍本专业中的实用技术、前沿领域或发展趋势等，以扩展学生的知识面。

本书内容丰富，各个学校在教学过程中可根据具体的专业特点和本校的实际情况来选取讲授的内容，当然更鼓励学有余力的学生在课余自学，这对开阔专业视野和提高专业英语的读写能力都是极有意义的。应当指出的是，如果没有充分的预习，仅靠课堂的讲授，相应的学习效果是十分有限的。

本书由河南科技学院李国厚、长春理工大学王春阳任主编，吉林工程技术师范学院尹振红和河南工业大学侯宏业任副主编。参加本书编写的还有合肥工业大学张晓江、西安科技大学王枫、河南工业大学王秀霞和河南科技学院高淑萍、邵锋。其中 Lesson 1、2、3 由李国厚编写，Lesson 4、5、11、17 由尹振红编写，Lesson 6、7 由高淑萍编写，Lesson 8、9、10、12 由张晓江编写，Lesson 13、14、21 由王秀霞编写，Lesson 15、16、18、19、20 由王春阳编写，Lesson 22、23、24、25 由王枫编写，附录 1～5 由邵锋编写，各课中的 Translating Skills(翻译技巧)及 Application Skills(应用技巧)部分均由侯宏业编写，全书由李国厚统稿并审定。

本书在编写过程中得到了孔晓红和沈宏两位老师提供的大量资料和无私帮助，同时参考了很多同仁的教材，在此一并表示感谢！

由于时间仓促，加之编者水平所限，书中的疏漏或谬误之处在所难免，特别是课文注释和参考翻译部分，敬请广大读者批评指正。

编　者

2006 年 6 月

目　　录

Lesson 1 Analog Amplifiers

At the most basic level, a signal amplifier does exactly what you expect – it makes a signal bigger! However, the way in which it is done does vary with the design of the actual amplifier, the type of signal, and the reason why we want to enlarge the signal. [1] We can illustrate this by considering the common example of a "Hi-Fi" audio system.

In a typical modern Hi-Fi: system, the signals will come from a unit like a CD player, FM tuner, or a Tape/Minidisk unit. The signals they produce have typical levels of the order of 100 mV or so when the music is moderately loud. This is a reasonably large voltage, easy to detect with something like an oscilloscope or a voltmeter. However, the actual power levels of these signals are quite modest. Typically, these sources can only provide currents of a few milliamps, which by $P=VI$ means powers of just a few milliwatts. A typical loudspeaker will require between a few Watts and perhaps over 100 Watts to produce loud sound. Hence we will require some form of ***Power Amplifier*** (PA) to "boost" the signal power level from the source and make it big enough to play the music.

Fig. 1.1 shows four examples of simple analog amplifier stages using various types of device. In each case the a.c. voltage gain will usually be approximated by

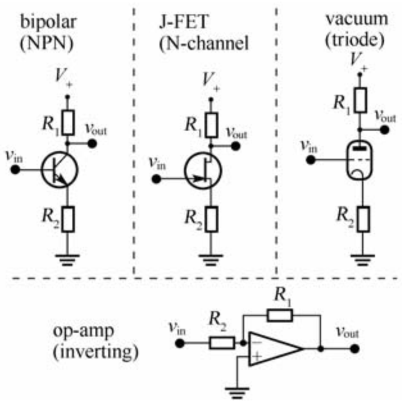


Fig. 1.1 Examples of voltage amplifiers

$$A_v \approx -R_1/R_2 \tag{1-1}$$

provided that the actual device has an inherent gain large enough to be controlled by the resistor values chosen.Note the negative sign in expression 1-1 which indicates that the examples all invert the signal pattern when amplifying. [2] In practice, gains of the order of up to hundred are possible from simple circuits like this, although it is usually a good idea to keep the voltage gain below this. Note also that vacuum state devices tend to be called "valves" in the UK and "tubes" in the USA.

Many practical amplifiers chain together a series of analog amplifier ***stages*** to obtain a high overall voltage gain. For example, a PA system might start with voltages of the order of 0.1 mV from microphones, and boost this to perhaps 10 to 100 V to drive loudspeakers. This requires an overall voltage gain of 10^9, so a number of voltage gain stages will be required.

In many cases we wish to amplify the current signal level as well as the voltage. The example we can consider here is the signal required to drive the loudspeakers in a "Hi-Fi" system. These will tend to have a typical input impedance of the order of 8 Ohms. So to drive, say, 100 Watts into such a loudspeaker load we have to simultaneously provide a voltage of 28 V_{rms} and 3.5 A_{rms}. Taking the example of a microphone as an initial source again a typical source impedance will be around 100 Ohms. Hence the microphone will provide just 1 nA when producing 0.1 mV. This means that to take this and drive 100 W into a loudspeaker the amplifier system must amplify the signal current by a factor of over 10^9 at the same time as boosting the voltage by a similar amount. [3] This means that the overall power gain required is 10^{18} – i.e. 180 dB!

This high overall power gain is one reason it is common to spread the amplifying function into separately boxed pre- and power-amplifiers. The signal levels inside power amplifiers are so much larger than these weak inputs that even the slightest 'leakage' from the output back to the input may cause problems. By putting the high-power (high current) and low power sections in different boxes we can help protect the input signals from harm.

In practice, many devices which require high currents and powers tend to work on the basis that it is the signal voltage which determines the level of response, and they then draw the current they need in order to work. [4] For example, it is the convention with loudspeakers that the volume of the sound should be set by the voltage applied to the speaker. Despite this, most loudspeakers have an efficiency (the effectiveness with which electrical power is converted into acoustical power) which is highly frequency dependent. To a large extent this arises as a natural consequence of the physical properties of loudspeakers. We won't worry about the details here, but as a result a loudspeaker's input impedance usually varies in quite a complicated manner with the frequency. (Sometimes also with the input level.)

Fig. 1.2 shows a typical example. In this case, the loudspeaker has an impedance of around 12 Ohms at 150 Hz and 5 Ohms at 1 kHz. So over twice the current will be required to play the same output level at 1 kHz than is required at 150 Hz. The power amplifier has no way to "know in advance" what kind of loudspeaker you will use, so simply adopts the convention of asserting a voltage level to indicate the required signal level at each frequency in the signal and supplying whatever current the loudspeaker then requires.

This kind of behavior is quite common in electronic systems. It means that, in information terms, the signal pattern is determined by the way the voltage varies with time, and ideally the current required is then drawn. Although the above is based on a high-power example, a similar situation can arise when a sensor is able to generate a voltage in response to an input stimulus but can only supply a very limited current. In these situations we require either a ***current amplifier*** or a ***buffer***. These devices are quite similar, and in each case we are using some form of gain device and circuit to increase the signal current level. However, a current amplifier always tries to multiply the current by a set amount. Hence it is similar in action to a voltage amplifier which always tries to multiply the signal current by a set amount. The buffer differs from the current amplifier as it sets out to provide whatever current level is demanded from it in order to maintain the signal voltage told to ***assert***. Hence it will have a higher current gain when connected to a more demanding load.

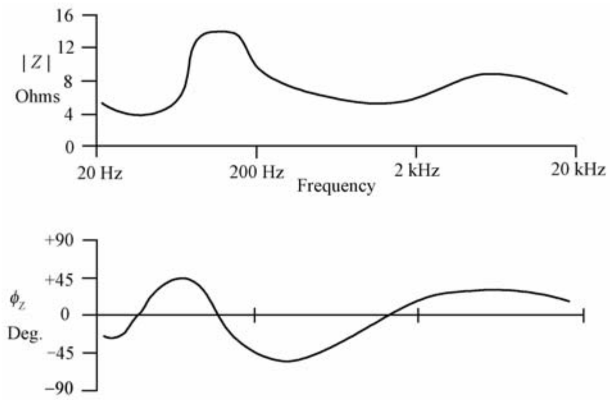


Fig 1.2 Impedance properties of a typical "8 Ohms" loudspeaker

New Words and Phrases

1. analog [ˈænəlɔg]	n.	类似物，相似体，模拟量
	adj.	模拟的
2. amplifier [ˈæmpliˌfaiə]	n.	[电工]扩音器，放大器
3. illustrate [ˈiləstreit]	vt.	举例说明，阐明，图解，加插图于
	vi.	举例
4. audio [ˈɔːdiəu]	adj.	音频的，声频的，声音的
	n.	音响，声音信号
5. Hi-Fi [ˈhaiˈfai]	n.	hi-fis(收音机、录音机等)具有高保真度
	abbr.	(略语)高保真(High-Fidelity)
6. fidelity [fiˈdeliti]	n.	忠实，诚实，忠诚，(收音机，录音设备等的)逼真度，保真度
7. minidisk [ˈminidisk]	n.	小型磁盘
8. approximate [əˈprɔksimeit]	adj.	近似的，大约的
	vt., vi.	(常与 to 连用)近似，接近
9. provided that		假如，倘若，如果，在……的条件下
10. of the order of		大约，左右，约与……相同(似)，达到……数量(= in the order of)
11. FM	abbr.	(略语)调频(frequency modulation)

12. tuner [ˈtjuːnə]	n.	调谐器，调谐电路，调音者，定弦者
13. moderately [ˈmɔdəritli]	adv.	适度地，稳健地
14. oscilloscope [ɔˈsiləskəup]	n.	[物]示波镜，示波器，示波管
15. voltmeter [ˈvəultˌmiːtə(r)]	n.	伏特计，电压表
16. milliwatt [ˈmiliwɔt]	n.	毫瓦
17. milliampere [ˌmiliˈæmpɛə]	n.	[电]毫安培
18. a.c.	abbr.	(略语)交流电(alternating current)
19. gain [gein]	n.	增益，财物的增加，利润，收获
	vt.	得到，增进，赚到，vi.获利，增加
20. voltage gain		电压增益
21. impedance [imˈpiːdəns]	n.	[电]阻抗，全电阻
22. resistor [riˈzistə]	n.	[电] 电阻，电阻器
23. valve [vælv]	n.	阀，活门，气门，[英]电子管，真空管(心脏)瓣膜，(贝类的)壳瓣
24. tube [ˈtjuːb]	n.	管，管子，[英]地铁，<美>电子管，显像管
25. bipolar [baiˈpəulə]	adj.	双极的，有两极的，两相的
26. FET	abbr.	(略语)场效应管(Field-effect transistor)
27. J-FET		J 型场效应管
28. N-channel		N 沟道
29. inverting [inˈvəːtiŋ]	adj.	反相的，倒相的
30. boost [buːst]	vt.	推进，增加，增进，升压，拔高，改善
	n.	上推，增加，提高，帮助，鼓舞
31. triode [ˈtraiəud]	n.	[电子]三极管，真空三极管
32. op-amp	abbr.	(略语)运算放大器(operational amplifier)
33. current [ˈkʌrənt]	adj.	当前的，通用的，流通的，草写的，最近的
	n.	涌流，趋势，电流
34. in advance		提前，事前，预先
35. simultaneously [siməlˈteiniəsly; (*US*) saim-]	adv.	同时地
36. convention [kənˈvenʃən]	n.	大会，会议，协定，条约，协议，契约，习俗，惯例
37. overall power		总功率
38. applied [əˈplaid]	adj.	应用的，实用的，施加的，外加的
39. acoustical [əˈkuːstik(ə)l]	adj.	听觉的，声学的
40. consequence [ˈkɔnsikwəns]	n.	结果，[逻]推理，推论，因果关系，重要的地位
41. sensor [ˈsensə]	n.	传感器，灵敏元件
42. stimulus [ˈstimjuləs]	n.	刺激，刺激物，促进因素[复数]stimuli
43. buffer [ˈbʌfə]	n.	缓冲器，缓冲物，缓冲区

	vt.	缓冲
44. in action		在活动，在运转，在工作，起作用，在运行中
45. assert [əˈsəːt]	vt.	断言，声称，主张，维护，表明
46. Ohm [əum]	n.	欧姆(①姓氏 ②Georg Simon，1787—1854，德国物理学家) [电]欧姆
47. Hz	abbr.	(略语)hertz [həːts]
	n.	赫，赫兹(频率单位：周/秒)赫兹 ①姓氏 ②Gustav, 1887—1975, 德国物理学家，曾获 1925 年诺贝尔物理学奖
48. demanding [diˈmɑːndiŋ; (*US*) diˈmændiŋ]	adj.	过分要求的，苛求的，费力的，需要技能的，要求高的

Notes

[1] However, the way in which this is done does vary with the design of the actual amplifier, the type of signal, and the reason why we want to enlarge the signal.

然而，信号的放大方式随着实际放大器的设计、信号的类型以及放大信号目的的不同而变化。

本句为强调句型，句中的定语从句 in which this is done 修饰主语 the way，does 用于强调谓语 vary。短语结构 the design of the actual amplifier 与 the type of signal 及 and the reason why we want to enlarge the signal 并列作为介词 with 的宾语。why 引导的定语从句修饰 the reason。

[2] Note the negative sign in expression 1-1 which indicates that the examples all invert the signal pattern when amplifying.

注意，表达式 1-1 中的负号说明，示例中的电路在放大时改变了信号的极性。

句中 which 引导的定语从句和介词短语 in expression 1-1 修饰动词 Note 的宾语 the negative sign，that 引导的宾语从句在定语从句中作宾语，副词 all 和分词结构 when amplifying 修饰谓语动词 invert。

[3] This means that to take this and drive 100 W into a loudspeaker the amplifier system must amplify the signal current by a factor of over 10^9 at the same time as boosting the voltage by a similar amount.

这就表示要接受这种输入信号并去驱动 100 瓦的扬声器，放大电路就必须将信号的电流和电压同时放大 10^9 倍。

句中 that 引导的从句作谓语动词 means 的宾语，不定式短语 to take…在宾语从句中作目的状语，by a factor…为从句中的方式状语。

[4] In practice, many devices which require high currents and powers tend to work on the basis that it is the signal voltage which determines the level of response, and they then draw the current they need in order to work.

实际上，许多需要大电流和大功率的设备往往都在特定的条件下工作，即由信号的电

压决定响应的幅度，继而由设备吸收其所需要的电流而工作。

句中 which 引导的定语从句修饰主语 many devices，介词短语 on the basis 作状语，that 引导的定语从句修饰 the basis，which 引导的从句定语修饰 the signal voltage，they need 为省略了关系代词的定语从句，修饰 draw 的宾语 the current。

Translating Skills　科技英语翻译概述

随着科学技术的迅猛发展，新技术、新学科、新材料、新工艺的不断出现，各层次技术交流的日益频繁，很多用英语撰写的科技文献大量出现。20 世纪 70 年代以来科技英语在教育领域逐渐成为一种专业，对科技英语的研究也在不断深入，在科技翻译方面出版了大量的论文、专著，来探讨这种科技英语的翻译理论和翻译方法。科技英语是指科技文体，包括英语科技论文、科技报告、科普文章、科技新闻和科技产品说明书等与科技有关的各种文献，它有别于一般英语和文学英语。因此对科技文体的翻译也有别于其他文体的翻译。要搞好科技英语翻译就要了解科技英语的词汇、语法、句法和特征，熟悉科技英语的思维翻译过程，掌握科技英语的翻译原则和标准，懂得科技英语的翻译技巧，学习有关的专业知识，打好扎实的功底。

科技英语文体的特点

1. 词汇特征

科技文体承载着探索自然奥秘，揭示客观事物发展规律的信息，所传递的是客观真理，客观事实，因此必须使用表意准确的专业术语。专业术语是专业领域的概念名词，来源广泛，有来源于日常生活的术语词也叫准专业术语，但大量的术语主要来源于希腊语和拉丁语的词语，因此其词形固定，词义单一，不容易混淆。同时不同领域的科技术语其语义具有明确的层次结构，简明扼要，相对固定，具有国际通用性。由于希腊语和拉丁语的词缀丰富，有极强的构词能力，因此以它们为主要来源的科技术语在构词方面也有此特征。如 copper end rings 铜端环(名词+名词)，magnetic moment 磁力矩(形容词+名词)，alternating current 交流电(ing 分词+名词)，field winding 励磁绕组(名词+ing 名词)，output 输出(小品词+动词)，printed circuit 印制电路(ed 分词+名词)，I-cursor I 形光标(大写字母+名词)，modern control system 现代控制系统(形容词+名词+名词中心词)，autochart 自动流程图(auto 前缀)，speedmeter 速度计(meter 后缀)，techicolor 彩色摄影(“i”中缀) 。翻译时把英语和汉语的构词法和语义特性结合起来，采用音译、意译、形译、象译或音意结合的方法，达到准确、简洁、通俗易懂。如在翻译 bi-stable circuit 时，结合汉语的四字结构的表达习惯，翻译成“双稳电路”要比“双稳态电路”简洁。

2. 语法、句法特征

科技文献概括事物发展的规律，陈述客观事实的存在，突出所述事实，因此多使用一般现在时和被动语态。为了严密表达事物之间的逻辑和先后、主次关系，多使用带有介词短语、形容词短语、分词短语、不定式短语、同位语从句、定语从句或状语从句等修饰语的长句。为了叙述方便，常使用以 it 为形式主语的句型。如：

The signal levels inside power amplifiers are so much larger than these weak inputs that even the slightest ‘leakage’ from the output back to the input may cause problems.

功率放大器中的信号幅度比微弱的输入信号大得多，即使输出的极微小的泄漏传输到输入端，都会引发一些问题。

For example, it is the convention with loudspeakers that the volume of the sound should be set by the voltage applied to the speaker.

例如，扬声器的音量通常是受所加电压控制。

科技英语翻译的标准与原则

科技翻译的对象十分广泛，涉及专著、论文、专利说明书、实验报告和会议记录等各种材料，要想把严谨的英语科技文献准确无误、通顺流畅地翻译成汉语，就要遵循一定的标准和原则。关于翻译的标准国内外提出了不少理论，国内从严复的“信、达、雅”到鲁迅的“信、顺”，到茅盾的“意境”，傅雷的“神似”，钱钟书的“化境”；国外的有前苏联费道罗夫的“等值”理论，美国翻译家尤金·奈达的“语言学-符号学”翻译理论，美国语言学家 W.Mann 和 S.Thompson 的“语篇分类学说”，韩礼德和哈桑的“衔接”理论。这些翻译理论在科技英语翻译中也适用。权衡概括这些理论，在科技翻译中有人提出了已得到公认的两种标准。

1. 忠实原文

指译者把原文所包含的概念、事理、思想、论点、结论、方法，即原作表达的一切信息包括语言形式、语言意义和思想逻辑忠实、准确地传达出来。

2. 语句通顺流畅、简洁自然，语言通俗易懂、符合译入语规范

由于科技文体重视严密的逻辑性，语言庄重规范，翻译时常采用直译法。但译者一定要仔细研读原文，不能因拘泥于形式而讲究语法、句子成分和语序的完全对等，致使译文晦涩难懂。要根据句子内部的逻辑关系和汉语的表达习惯适当调整语序，必要时增加或省略一些词，用简洁、精炼、通俗易懂的语言再现其思想内容、语体风格和感情色彩。

搞好科技英语翻译应具备的条件

想翻译出一篇好的科技文体的文章来，并不是一件容易的事。仅仅依靠对英语的掌握或对汉语的文字驾驭能力，都不能搞好科技翻译。因为科技翻译是一个复杂的过程，涉及多方面的素质，必须综合各方面的因素。

1. 科学严谨的态度

历数翻译界的专家学者所从事的翻译事业，可以看出他们付出了艰辛劳动，耗费了很多精力，进行了大量实践，呈现给读者一篇篇值得反复阅读的优秀译文，给我们带来知识、带来美感、带来享受。从中了解到他们严谨的翻译态度。科技翻译必须严肃认真，一丝不苟，勤查词典，不能想当然的主观猜测。一个词、一个符号、一个数字都须准确理解其作用、含义。

2. 良好的英语语言基础

熟练掌握英语是进行英汉转换的前提。对英语一知半解，就不能很好地理解原文，更

无从谈起翻译，也就不可能有好的译作。事实证明，没有扎实的英语基础，仅凭词典加翻译机器加原文是搞不好科技翻译的。

3. 熟练地驾驭汉语的能力

同样，没有熟练地驾驭汉语语言的能力，即使理解得很透彻，翻译出来的文字不是晦涩难懂，就是语义模糊，也让人似懂非懂。

4. 广博的专业及相关领域的知识

当今科技发展迅速，学科之间交叉渗透普遍，一个领域里会有另外领域的知识。因此，只有经常学习本专业和相关专业的知识，才能胜任科技翻译。

5. 必要的英语翻译理论和技巧

理论是指导实践的有效工具，有时一个段落、一个句子或一个术语，尽管了然于心，但往往苦于找不到合适的方法进行翻译，令人非常苦恼。必要理论的知识会使人豁然开朗。

6. 大量实践经验的积累

范武邱先生所编著的《实用科技英语翻译讲评》(P76)中有一句话说得非常好：一般认为，没有十万字的翻译实践而去谈理论基本上是纸上谈兵，其实用性和可操作性让人生疑。从中可见翻译实践经验的积累对搞好翻译至关重要。

Exercises

1. Translate the following into Chinese.

(1)A bipolar junction transistor (BJT) is a three-layer silicon (or germanium) device consisting of either two *p*- and one *n*-type layers of materials (*pnp*) or two *n*- and one *p*-type layers of materials (*npn*).

(2)Since the emitter follower has a high input impedance and a low output impedance, its voltage gain is less than unity and the power gain is normally lower than that obtained from other configurations.

(3)The current in a reverse-biased diode is small (typically 10^{-8} A for silicon) and approximately independent of voltage until the breakdown region at high reverse voltages is reached.

(4) Most integrated circuits provide the same functionality as “discrete” semiconductor circuits at higher levels of reliability and at a fraction of the cost.

(5) Vision is well developed in most snakes, but many burrowing snakes are virtually blind.

(6) Working out regularly may make you smarter now and lessen the possibility that you will lose brain function as you age.

(7) They work out a new method by which production has now been rapidly increased.

2. Translate the following into English.

(1) 模拟放大器根据设定的放大倍数对模拟电压或电流信号进行放大，以推动负载工作。

(2) 放大器的增益就是放大倍数，用于表示放大器对小信号的放大能力。

(3) 很多实际应用系统中的放大电路都通过级联多级放大器来提高放大倍数。

(4) 模拟电路用于处理在 0 伏到电源电压之间任意变化的信号。

(5) 航天员同其他任何人一样，会随身把微生物(microbes) 携带到他们去的任何地方。

(6) 研究睡眠的长远目标就是对入睡和清醒两者之间的联系予以全面说明。

(7) 已下令将目前在太空实验室里的研究人员送回来。

Reading Material Analog circuits

Analog circuits are circuits dealing with signals free to vary from zero to full power supply voltage. This stands in contrast to digital circuits, which almost exclusively employ “all or nothing” signals: voltages restricted to values of zero and full supply voltage, with no valid state in between those extreme limits. Analog circuits are often referred to as linear circuits to emphasize the valid continuity of signal range forbidden in digital circuits, but this label is unfortunately misleading. Just because a voltage or current signal is allowed to vary smoothly between the extremes of zero and full power supply limits does not necessarily mean that all mathematical relationships between these signals are linear in the “straight-line” or “proportional” sense of the word. Many so-called “linear” circuits are quite nonlinear in their behavior, either by necessity of physics or by design.

The circuits make use of IC, or integrated circuit, components. Such components are actually networks of interconnected components manufactured on a single wafer of semiconducting material. Integrated circuits providing a multitude of pre-engineered functions are available at very low cost, benefiting students, hobbyists and professional circuit designers alike. Most integrated circuits provide the same functionality as “discrete” semiconductor circuits at higher levels of reliability and at a fraction of the cost. Usually, discrete-component circuit construction is favored only when power dissipation levels are too high for integrated circuits to handle.

Perhaps the most versatile and important analog integrated circuit for the student to master is the operational amplifier, or op-amp. Essentially nothing more than a differential amplifier with very high voltage gain, op-amps are the workhorse of the analog design world. By cleverly applying feedback from the output of an op-amp to one or more of its inputs, a wide variety of behaviors may be obtained from this single device. Many different models of op-amp are available at low cost.

A comparator circuit compares two voltage signals and determines which one is greater. The result of this comparison is indicated by the output voltage: if the op-amp’s output is saturated in the positive direction, the noninverting input (+) is a greater, or more positive, voltage than the inverting input (-) , all voltages measured with respect to ground. If the op-amp’s voltage is near the negative supply voltage (in this case, 0 Volt, or ground potential) , it means the inverting input (-) has a greater voltage applied to it than the noninverting input (+) Y.

This behavior is much easier understood by experimenting with a comparator circuit than it is by reading someone’s verbal description of it. In this experiment, two potentiometers supply variable voltages to be compared by the op-amp. The output status of the op-amp is indicated visually by the LED. By adjusting the two potentiometers and observing the LED, one can easily comprehend the function of a comparator circuit.

New Words and Phrases

1. exclusively [ikˈsklu:sivli]	adv.	排外地，排他地，独占地，专有地
2. valid [ˈvælid]	adj.	[律]有效的，有根据的，正当的，公正的，正确的
3. component [kəmˈpəunənt]	n.	元件，零件，成分
	adj.	组成的，构成的
4. wafer [ˈweifə]	n.	晶片，圆片，薄饼，干胶片，[宗]圣饼
	vt.	用干胶片封
5. multitude [ˈmʌltitju:d]	n.	多数，群众，平民，大量，众多
6. preengineered [pri:ˈendʒiˈniəd]	n.	用预造件的，组合的
7. dissipation [disiˈpeiʃ(ə)n]	n.	驱散，消散，浪费，放荡
8. versatile [ˈvə:sətail]	adj.	通用的，万能的，多才多艺的，多面手的
9. workhorse [ˈwə:khɔ:s]	n.	驮马，做粗工者，重负荷机器，骨干，主力，主要设备
10. saturated [ˈsætʃəreitid]	adj.	饱和的，渗透的，深颜色的
11. positive [ˈpɔzətiv]	adj.	肯定的，实际的，积极的，绝对的，确实的，[数]正的，[电]阳的，[语法]原级的
12. negative [ˈnegətiv]	n.	否定，负数，底片
	adj.	否定的，消极的，负的，阴性的
	vt.	否定，拒绝(接受)
13. verbal [ˈvə:bəl]	adj.	口头的，语言的，用词的，动词的
	n.	语言，词句，口头，动词
14. variable [ˈvɛəriəbl]	n.	[数]变数，可变物，变量
	adj.	可变的，不定的，易变的，变量的
15. potentiometer [pəˌtenʃiˈɔmitə]	n.	电位计，分压计，分压器，电位器
16. discrete component		分立元件
17. nothing more than		仅仅，只不过
18. LED	abbr.	(略语)发光二极管 (light-emitting diode)
19. diode [ˈdaiəud]	n.	二极管，电子二极管，半导体二极管

Lesson 2 Basic Circuits of Operational Amplifiers

Operational Amplifiers (OAs) are highly stable, high gain dc difference amplifiers. Since there is no capacitive coupling between their various amplifying stages, they can handle signals from zero frequency (dc signals) up to a few hundred kHz. Their name is derived by the fact that they are used for performing ***mathematical operations*** on their input signal(s) .

Fig. 2.1 shows the symbol for an OA. There are two inputs, the ***inverting input*** (−) and the ***non-inverting input*** (＋) .These symbols have nothing to do with the polarity of the applied input signals. Connections to power supplies are also shown..

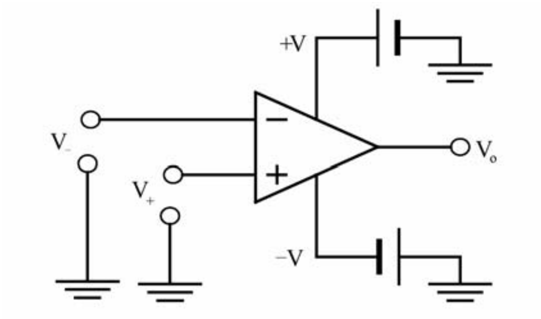


Fig. 2.1 Symbol of the operational amplifier

The output signal (voltage) , v_o, is given by:

$$v_o = A(v_+ - v_-) \qquad (2\text{-}1)$$

v_+ and v_- are the signals applied to the non-inverting and to the inverting input, respectively. A represents the ***open loop gain*** of the OA. A is infinite for the ideal amplifier, whereas for the various types of real OAs, it is usually within the range of 10^4 to 10^6.

OAs require two power supplies to operate, supplying a positive voltage (＋V) and a negative voltage (－V) with respect to circuit common. This bipolar power supply allows OAs to generate output signals (results) of either polarity. The output signal (v_o) range is not limited. The voltages of the power supplies determine its actual range. Thus, a typical OA fed with －15 V and ＋15 V may yield a v_o within the (approximately) －13 V to ＋13 V range, which is called ***operational range***. Any result expected to be outside this range is clipped to the respective limit, and OA is in a ***saturation*** stage.

The connections to the power supplies and to the circuit common symbols, shown in Fig. 2.1, hereafter will be implied, and they will be not shown in the rest of the circuits for simplicity.

Because of their very high open loop gain, OAs are almost exclusively used with some additional circuitry (mostly with resistors and capacitors) required to ensure a negative feedback loop. Through this loop a tiny fraction of the output signal is fed back to the inverting input. The negative feedback stabilizes the output within the operational range and provides a much smaller but precisely controlled gain, the so-called ***closed loop gain***. [1]

Circuits of OAs have been used in the past as analog computers, and they are still in use for mathematical operations and modification of the input signals in real time. A large variety of OAs is commercially available in the form of low cost integrated circuits.

There is a plethora of circuits with OAs performing various mathematical operations. Each circuit is characterized by its own ***transfer function***, i.e. the mathematical equation describing the output signal (v_o) as a function of the input signal (v_i) or signals (v_1, v_2, …, v_n). Generally, transfer functions can be derived by applying Kirchhoff's rules and the following two simplifying assumptions:

(1) The output signal (v_o) acquires a value that (through the feedback circuits) practically equates the voltages applied to both inputs, i.e. $v_+ \approx v_-$.

(2) The input resistance of both OA inputs is extremely high (usually within the range $10^6 \sim 10^{12}$ MΩ, for the ideal OA it is infinite) , thus no current flows into them.

The basic circuit of the ***inverting amplifier*** is shown in Fig. 2.2.

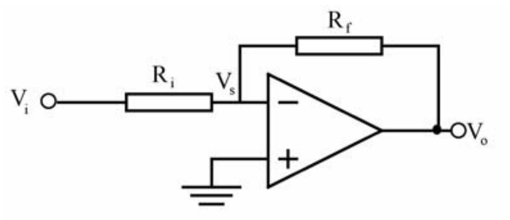


Fig. 2.2　Inverting amplifier

The transfer function is derived as follows: Considering the arbitrary current directions we have:

$$i_1 = (v_i - v_s)/R_i \quad \text{and} \quad i_2 = (v_s - v_o)/R_f \tag{2-2}$$

The non-inverting input is connected directly to the circuit common (i.e. $v_+ = 0$ V) , (considering simplifying assumption 1) $v_s = v_- = 0$ V, therefore:

$$i_1 = v_i / R_i \quad \text{and} \quad i_2 = -v_o / R_f \tag{2-3}$$

Since there is no current flow to any input (simplifying assumption 2) , it is:

$$i_1 = i_2 \tag{2-4}$$

Therefore, the transfer function of the inverting amplifier is:

$$v_o = -(R_f / R_i) v_i \tag{2-5}$$

Thus, the closed loop gain of the inverting amplifier is equal to the ratio of R_f (feedback resistor) over R_i (input resistor). This transfer function describes accurately the output signal as long as the closed loop gain is much smaller than the open loop gain A of the OA used (e.g. it must not exceed 1000) , and the expected values of v_o are within the operational range of the OA. [2]

The ***summing amplifier*** is a logical extension of the previously described circuit, with two or more inputs. Its circuit is shown in Fig. 2.3.

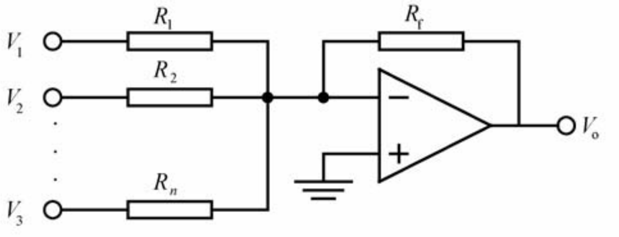


Fig. 2.3 Summing amplifier

The transfer function of the summing amplifier (similarly derived) is:

$$v_o = -(v_1/R_1 + v_2/R_2 + \ldots + v_n/R_n)R_f \tag{2-6}$$

Thus if all input resistors are equal, the output is a scaled sum of all inputs, whereas, if they are different, the output is a weighted linear sum of all inputs.

The summing amplifier is used for combining several signals. The most common use of a summing amplifier with two inputs is the amplification of a signal combined with a subtraction of a constant amount from it (dc offset).

Difference amplifier precisely amplifies the difference of two input signals. Its typical circuit is shown in Fig. 2.4.

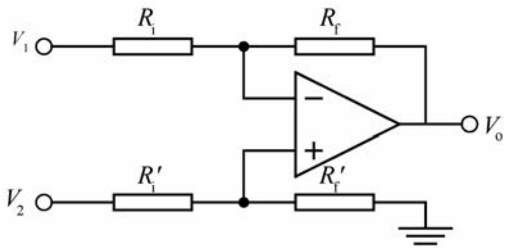


Fig. 2.4 Difference amplifier

If $R_i = R_i'$ and $R_f = R_f'$, then the transfer function of the difference amplifier is:

$$v_o = (v_2 - v_1)R_f / R_i \tag{2-7}$$

The difference amplifier is useful for handling signals referring not to the circuit common, but to other signals, known as ***floating signal*** sources. Its capability to reject a common signal makes it particularly valuable for amplifying small voltage differences contaminated with the same amount of noise (common signal). [3]

In order for the difference amplifier to be able to reject a large common signal and to generate at the same time an output precisely proportional to the two signals difference, the two ratios $p = R_f/R_i$ and $q = R_f'/R_i'$ must be precisely equal, otherwise the signal output will be:

$$v_o = [q(p+1)/(q+1)]v_2 - pv_1 \tag{2-8}$$

The ***differentiator*** generates an output signal proportional to the first derivative of the input with respect to time. Its typical circuit is shown in Fig. 2.5.

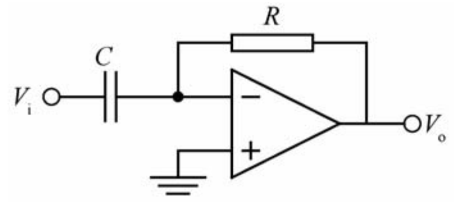


Fig. 2.5　Differentiator

The transfer function of this circuit is

$$v_o = -RC(\mathrm{d}v_i / \mathrm{d}t) \tag{2-9}$$

Obviously, a constant input (regardless of its magnitude) generates a zero output signal. A typical usage of the differentiator in the field of chemical instrumentation is obtaining the first derivative of a potentiometric titration curve for the easier location of the titration final points (points of maximum slope). [4]

The ***integrator*** generates an output signal proportional to the time integral of the input signal. Its typical circuit is shown in Fig. 2.6.

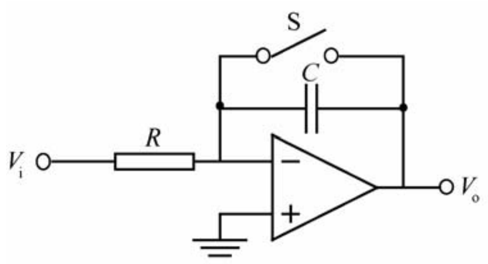


Fig. 2.6　Integrator

$$v_o = -(1/RC)\int v_i(t)\mathrm{d}t \tag{2-10}$$

In Fig. 2.6, the output remains zero as far as switch S remains closed. The integration starts (t＝0) when S opens. The output is proportional to the charge accumulated in capacitor C, which serves as the integrating device. A typical application of the (analog) integrator in chemical instrumentation is the integration of chromatographic peaks, since its output will be proportional to the peak area.

If the input signal is stable, then the output from the integrator will be given by the equation:

$$v_o = -(v_i / RC)t \tag{2-11}$$

i.e. the output signal will be a voltage ramp. Voltage ramps are commonly used for generating the linear potential sweep required in polarography and many other voltammetric techniques.

New Words and Phrases

1. stable [ˈsteib(ə)l]	adj.	固定的，稳定的，不动摇的，坚定的，可靠的
	n.	畜栏，厩，马房
2. dc	abbr.	(略语)直流电(direct current)
3. difference amplifier		差频信号放大器，差分放大器，差动放大器

4. coupling [ˈkʌpliŋ]	n.	联结，接合，耦合
5. derive [diˈraiv]	vt.	(常与 from 连用)得来，得到
		来自，源自，出自
	vi.	起源
6. capacitive [kəˈpæsitiv]	adj.	电容性的，电容的
7. invert [inˈvəːt]	vt.	使颠倒，使转化
8. inverting input		倒相输入，反相输入
9. non-inverting input		非反相输入，同相输入
10. open loop gain		开环增益
11. polarity [pəuˈlæriti]	n.	极性，正负极，对立，极端
12. with respect to		关于，至于，谈到
13. clip [klip]	n.	夹子，回形针，子弹夹
	vt.	夹住，剪短，修剪，钳位
14. yield [jiːld]	vt.	出产，生长，生产
	vi.	(～to)屈服，屈从
	n	产量，收益
15. saturation [ˌsætʃəˈreiʃən]	n.	饱和(状态)，饱和度，浸润，浸透
16. hereafter [hiərˈɑːftə]	adv.	今后，从此以后
17. circuitry [ˈsəːkitri]	n.	电路，线路，电路系统，电路元件，电路学
18. capacitor [kəˈpæsitə]	n.	(=capacitator)电容器
19. logical [ˈlɔdʒik(ə)l]	adj.	逻辑的，逻辑上的，逻辑学的，合乎逻辑的
20. extension [iksˈtenʃən]	n.	延长，扩充，范围，扩展名，(电话)分机
21. stabilize [ˈsteibilaiz]	vt.	使稳定，使稳固，使不变，使平衡
22. closed loop gain		闭环增益
23. real time		事情发生的同时，实际时间，[计]实时
24. low cost		低成本
25. integrate [ˈintigreit]	vt.	使成整体，使结合，合并，
		联合，使一体化，求……的积分
26. plethora [ˈpleθərə]	n.	过剩，过多，多血症
27. characterize [ˈkæriktəraiz]	vt.	表现……的特色，刻画的……性格
28. transfer function		转移函数，传递函数
29. Kirchhoff’s rules		克希霍夫定律
30. arbitrary [ˈɑːbitrəri]	adj.	任意的，武断的，独裁的，专断的
31. i.e. abbr. id est [idˈest] [拉]		(=that is(to say) 略作 i.e.)即，就是
32. assumption [əˈsʌmpʃən]	n.	假定，设想，担任，承当，假装，作态
33. e.g. abbr.		(略语) [拉] exempli gratia [igˈzemplaiˈgreiʃiə]
		＝for example 例如

34. scale [skeil]	n.	刻度，衡量，比例，数值范围
		比例尺，天平，等级
	vt.	依比例决定，测量
	vi.	剥落，生水垢，攀登，衡量
35. weighted [ˈweitid]	adj.	有利的，加权的，受力的
		负荷的，已称重的
36. constant [ˈkɔnstənt]	n	[数]常数，恒量
	adj.	不变的，持续的
		坚决的，固定的，忠实的
37. offset [ˈɔːfset]	n.	偏移量，抵消，弥补，分支
	vt.	弥补，抵消
	vi.	偏移，形成分支
28. common signal		共模信号
39. contaminate [kənˈtæmineit]	vt.	污染，弄脏，传染，感染
		损害，毒害，使腐败
40. differentiator [ˌdifəˈrenʃiˌeitə]	n.	微分器，区分者
41. regardless of		不管，不顾，不注意，与……无关
42. magnitude [ˈmægnitjuːd]	n.	大小，数量，巨大，广大
		量级，重要，重要性
43. derivative [diˈrivətiv]	adj.	引出的，系出的
	n.	导数，派生的事物，衍生物，派生词
44. instrumentation [ˌinstrumenˈteiʃən]	n.	使用仪器，特定用途的仪器
		配器，编写器乐曲
45. potentiometric [pəˌtenʃiˈɔmitrik]	adj.	电位[势]的
46. titration [taiˈtreiʃən]	n.	[化]滴定，滴定法
47. integrator [ˈintigreitə]	n.	积分仪(器，机，元件，装置)，
		求积器，综合者，合成者
48. integral [ˈintigrəl]	adj.	完整的，整体的，整数的[数学]
		积分的
	n.	[数学]积分，完整，整数
49. integration [ˌintiˈgreiʃən]	n.	综合，[数学]积分
50. charge [tʃɑːdʒ]	n.	电荷，负荷，费用，主管，
		充电，装料
	v.	装满，控诉，告诫，收费
51. chromatographic [ˌkrəumætəˈgræfik]	adj.	层离法的，色谱(分析)的，
		色谱法的，色谱仪的
52. equation [iˈkweiʃən]	n.	方程式，等式，相等，平衡，综合体
53. ramp [ræmp]	n.	斜坡，坡道，敲诈
	vi.	狂跳，乱撞，敲诈，蔓延
	vt.	使有斜面，敲诈

54. sweep [swiːp]	vt.	扫，打扫，清扫，席卷，冲光，扫过，掠过，[电子学]搜索，扫描
55. polarography [pəuləˈrɔgrəfi]	n.	[化]极谱法，极谱学
56. voltammetric [ˌvəultəˈmetrik]	adj.	[化]伏安法的

Notes

[1] The negative feedback stabilizes the output within the operational range and provides a much smaller but precisely controlled gain, the so-called *closed loop gain*.

负反馈使输出稳定在其工作范围内，并提供一个较小但控制准确的增益，即所谓闭环增益。

[2] This transfer function describes accurately the output signal as long as the closed loop gain is much smaller than the open loop gain A of the OA used (e.g. it must not exceed 1000) , and the expected values of v_o are within the operational range of the OA.

只要所用运放的闭环增益比开环增益 A 小得多(即不能超过 1000)，这个传递函数就能准确地描述输出信号，且 v_o 的预期值在运放的工作范围之内。

句中 as long as 引导的是条件状语从句。过去分词 used 作定语，修饰 the OA。

[3] Its capability to reject a common signal makes it particularly valuable for amplifying small voltage differences contaminated with the same amount of noise (common signal).

差动放大器抑制共模信号的能力使它特别适于放大受同样大小噪声(共模信号)干扰的小压差信号。

句中的不定式短语 to reject a common signal 作定语，修饰主语 Its capability。过去分词短语 contaminated…作定语，修饰现在分词结构中的宾语 differences。

[4] A typical usage of the differentiator in the field of chemical instrumentation is obtaining the first derivative of a potentiometric titration curve for the easier location of the titration final points (points of maximum slope).

微分器在化工仪表领域中的典型应用是获取为了便于确定最后滴定点(最大斜率点)在电压滴定曲线的位置的第一个微分值。

Translating Skills　英汉语序的对比及翻译

语序(word order)指各级语言单位在组合中的排序，主要指在句中作各种成分的词的排序，简称词序。总的来说，英语的语序灵活，汉语的语序固定。大多情况下，英汉都使用正常语序，且多有相似之处，英译汉时可按原文语序顺译。但有时英语为了强调，平衡句子，或衔接自然等因素也多用倒装句，英译汉时应灵活处理，译成符合汉语习惯的语序。

正常语序

英汉两种语言的句子成分都有主、谓、宾(表语)，且词序基本一致，译成汉语时可按自然语序；但英语定语和状语的语序有同有异，翻译时须灵活处理。如：

(1) We are trying our best to win success.

我们正在尽最大努力争取胜利。(陈述句，英汉词序一致)

(2) Who invented the telescope?

谁发明了这架望远镜？(特殊疑问句，英汉词序一致)

(3) What a fine day it is !

多晴朗的天呀！(感叹句，把 what 译成“多”，“多么”，增加“呀”，“啊”，英汉词序～致)

(4) Water is an **important** liquid.

水是一种**重要的**液体。(英语的单个词作前置定语−汉语的前置定语，英汉词序一致)

(5) That is something we really need today .

那是我们**今天真正需要的**东西。(定语从句修饰不定代词后置−汉语前置，类似的不定代词有 everything, nothing, anything , no one, anyone 等)

(6) We will try to get a ticket in **every** way **possible.**(以-ible, -able 结尾的形容词在句中作名词的后置定语时，常与 every, the only 或形容词最高级连用)

我们将**尽可能**买到票。(英语后置的单词定语−汉语前置)

(7) This is **the best** food **available.** (以-ible,-able 结尾的形容词在句中作名词的后置定语时，常与 every, the only 或形容词最高级连用)

这是**能得到的**最好的食物。

(8) All the people **nearby** gathered on the street to watch the spacecraft. (副词)

附近的所有人都聚到街上观看宇宙飞船。(英语后置的单词定语−汉语前置)

(9) The department **concerned** is taking measures to solve air pollution.**(分词)**

有关部门正采取措施解决空气污染问题。(英语后置的单词定语−汉语前置)

(10) The most important example **of an Internet** is referred to simple as Internet.

互联网最重要的一个例子就是直接称为因特网。(英语的介词短语后置−汉语前置)

(11) Many people think that man’s social practice alone is the criterion **of the truth of his knowledge of the external world.**

许多人认为，只有人的社会实践才是**他们对外界认识的真理性的**标准。(英语中几个介词短语连用作名词的后置定语−汉语词序颠倒翻译)

(12) Intranet is a **corporate Internet that provides the key** Internet applications.

内联网是一种**能提供基本因特网应用技术的公司内部**互联网。(一个句子中有两个定语，一个在修饰语的前面，一个在修饰语的后面−汉译时顺序多为后置修饰语+前置修饰语+被修饰词)

(13) He is **especially** good at learning languages.

他**尤其**擅长学习各种语言。(英语中副词修饰形容词前置−汉语前置)

(14) The rocket must go fast **enough** round the earth to balance the force of gravity.

火箭必须围绕地球运行得**足够快，**以抵消地心吸引力。(enough 常放在所修饰的形容词或副词后−汉译时前置)

(15) She **foolishly** asked the question.(英语副词修饰动词前置−汉语后置)

她问的问题是**愚蠢的**。

(16) She asked the question **foolishly.** (英语副词修饰动词后置−汉语前置)

她**愚蠢地**问了问题。(表示个性特征与智力的副词前置，如置于句末，句意会发生改变，如 cleverly, kindly 等)

(17) You shouldn’t stay up **too** late.

你不应睡**得太**晚。(英语前置-汉语前置，动词后加“得”)

(18) You, **too**, shouldn’t stay up late.

你**也**不应该睡得晚。(英语后置-汉语后置，修饰 you)

(19) **Also**, heating can make metals lose some of their strength.

此外，加热也会使金属损失掉他们的一些强度。(英语副词前置修饰整个句子-汉语前置)

(20) **Evidently** he was more than tired.

显然，他很疲倦。(英语副词前置修饰整个句子—汉语前置)

(21) He is **always** telling a lie.

他**总是**说谎。(频度副词汉译时常放在主要动词之前，类似的词有 seldom, already, often, never 等)

(22) The climate remains the same, **independent of the season of the year.**

不论四季如何变化，气候依然一样。(英语形容词短语后置—汉语后置)

(23) Air enters the engine through a divergent inlet duct, **in which its pressure is raised to some extent.**

空气通过扩散式进气管进入发动机，**其压力在此增大到一定程度。**(英语中非限制性定语从句后置-汉语后置)

(24) China successfully launched its spacecraft **in October 2005.**

中国**于 2005 年 10 月**成功地发射了一艘宇宙飞船。(英语的时间状语小的在前，大的在后—译成汉语次序相反。地点状语也有此特征)

倒装语序

英语为了假设、疑问、否定、强调、音韵平衡或衔接自然等因素也多用倒装句，而汉语这类句子相对较少。翻译时需认真对待。如：

(25) **There still seems** to be plenty of room in the bomb shelter for all his neighbours.

似乎**防空洞里还有**足够的空间让他的邻居躲身。(语序基本一致，只稍加调整，把地点状语放在存在“有”之前)

(26) **Never had** he had heard the name.

他**从没**听说过这个名字。(英语否定副词或短语移至句首—汉译时正常语序，添加“从不”，“再也”等语气词)

上述所讲并非没有例外。同时在英汉互译的过程中语序的灵活并不等于译者可以随意打乱次序；也不能因为过分强调尊重汉语的习惯而牺牲原句的意义和语义的连贯。

Exercises

1. Translate the following into Chinese.

(1) The direct-coupling technique used in an op-amp permits dc and ac amplification and ensures that the op-amp’s quiescent point will not drift with temperature change.

(2) Amplification is the process of increasing the magnitude of a variable quantity, especially the magnitude of voltage, power, or current, without altering any other quality.

(3) The voltage follower based on the op-amp has a very high input impedance and a very

low impedance so that the source and load are in effect isolated.

(4) It is conventional to call the two inputs inverting and non-inverting depending upon the sign of the resulting output and the gain when a signal is fed to the relevant input whilst the other is connected to zero Volts.

(5) We try to do a major market visit every month.

(6) Much of this covers the costs of paying high school teachers and college professors to grade the exams，Which include essays as well as multiple-choice questions.

(7) Telephones, TV parts, the computer mouse at your fingertips, parts inside a PC, and other everyday products are made with plastics using a process called injection molding.

2. Translate the following into English.

(1) 放大器通常是指利用晶体管来放大电压或电流小信号的仪器。

(2) 带反馈的闭环放大电路的电压增益一般用描述其输出和输入信号关系的传递函数表示，而与所用运放的开环增益 *A* 无关。

(3) 运放的输入电阻很大而输出电阻很小，非常便于信号的传递与耦合。

(4) 如果输入信号的传输距离远并可能有一些附加的干扰，差动放大器就特别有用。

(5) “禁止使用手机”的标牌到处可见。

(6) 是你而不是我打破了花瓶。

(7) 人们常说，电脑之所以能解决问题，只是因为他们给输入了解决问题的“程序”。

Reading Material　Class A　Amplifiers

Class A amplifiers always have had a good reputation among audiophiles. When talking about low power designs, these are in most cases designed as class A. Talking about audio power amplifiers, the picture is quite different. Here class B and A/B amplifiers play a dominant role, while class A is more seldom. In this article we will have a look at the different types.

To explain the difference between class A, B and A/B, it is easiest to look at the ***current amplifier*** itself. In Fig. 2.7 it is shown an example of a typical version with complementary transistors.

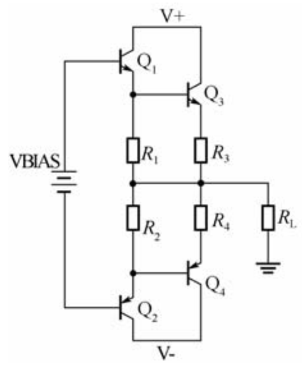


Fig. 2.7　The current amplifier

The transistors Q_1 and Q_2 make the drivers, while Q_3 and Q_4 make the power transistors. The resistors R_1 and R_2 determines the quiescent point for the drivers, while the resistors R_3 and R_4 prevent thermal "runaway" for the quiescent point *IQ* for the power transistors. The bias voltage *VBIAS* thus makes the quiescent current *IQ*. For class A operation nor Q_3 or Q_4 should be switched off at maximum voltage swing to the load *RL*.

Normally the quiescent current is calculated with the maximum continuous output power *P* in mind. Minimum quiescent current therefore will be found as *IQ* = sqrt(*P*/2*RL*). For *P* = 25 W RMS and *RL* = 8 ohm, *IQ* = 1.25 A is needed. This is half of the maximum current delivered to the load. Similarly, for 100 W RMS the demand is a quiescent current of minimum *IQ* = 2.5 A. The voltage swing at the load is a minimum of 20 V peak and 40 V peak, respectively. The power supply voltage should be chosen somewhat higher than this to allow voltage drop over transistors and resistors. When the loss in the drivers and the resistors are not taken into account, the power efficiency is 50 %. For 25 W RMS continuous output power, Q_3 and Q_4 accordingly dissipate 50 W, while these transistors for 100 W RMS continuous output power dissipate 200 W. Notice that the power efficiency for this push pull output stage is the double of the power efficiency of a "single ended" (constant current) output stage.

Now a number of 50 % for the power efficiency does not sound that bad, but it is calculated at full continuous output power. A music signal would be very boring if it consisted of one single tone and was played at maximum output level. In fact the power efficiency is much lower. It will depend on the load, the content of the music signal and the applied volume. The power loss however will be the same.

Consider the example with the 100 W amplifier, where the output transistors alone dissipate more than 200 W. This requires large heat sinks. Using a conventional heat sink as an example, having an effective thermal resistance of 0.25 W/K, the temperature will rise with more than 50 degrees above ambient temperature. Adding the fact that heat sinks not exactly are cheap, we already have two reasons to avoid class A drive.

New Words and Phrases

1. audiophile [ˈɔːdiəfail]	n.	高保真爱好者，讲究音质者，Hi-Fi 迷， 唱片爱好者，音乐爱好者
2. complementary transistor		互补晶体管
3. driver [ˈdraivə]	n.	驾驶员，驱动器，驱动程序， [机]起子，主动轮，传动器
4. power transistor		功率晶体管
5. quiescent [kwaiˈesənt]	adj.	静止的，安静的，休止的，不活动的
	n.	静止，静态，抑止
6. bias [ˈbaiəs]	n.	偏见，偏爱，偏差，斜线，嗜好，偏压，偏置
	vt.	使存偏见，加偏压到
	adj.	倾斜的，偏的，对角的

7. swing [swiŋ]	v.	摇摆，摆动，回转，旋转
	n.	秋千，摇摆，摆动
8. RMS	abbr.	(略语)Root Mean Square，均方根；Railway Mail Service，铁道邮政
9. respectively [ri'spektivli]	adv.	分别地，各个地，各自，相当，稍微
10. somewhat ['sʌm(h)wɔt]	adv.	稍微，有点，有些，相当
11. dissipate ['disipeit]	v.	驱散，(使)消散，浪费，消失，消耗
12. push pull output stage		推挽输出级
13. sink [siŋk]	vi.	沉下，(使)下沉，沉浸，使沉没，沉底，渗透
	n.	水槽，水池，接收器
14. heat sink		散热片，吸热设备，冷源，(半导体)热沉
15. ambient ['æmbiənt]	adj.	周围的，外界的
	n.	环境，外界条件，气氛，环境空间，包围物

Lesson 3 CMOS Logic Circuit

CMOS logic is a newer technology, based on the use of complementary MOS transistors to perform logic functions with almost no current required. [1] This makes these gates very useful in battery-powered applications. The fact that they will work with supply voltages as low as 3 Volts and as high as 15 Volts is also very helpful.

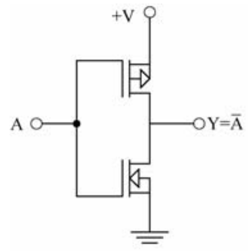


Fig. 3.1 CMOS Inverter

CMOS gates are all based on the fundamental inverter circuit shown in Fig. 3.1. Note that both transistors are enhancement- mode MOSFETs; one N-channel with its source grounded, and one P-channel with its source connected to ＋V. Their gates are connected together to form the input, and their drains are connected together to form the output.

The two MOSFETs are designed to have matching characteristics. Thus, they are complementary to each other. When off, their resistance is effectively infinite; when on, their channel resistance is about 200Ω. Since the gate is essentially an open circuit, it draws no current, and the output voltage will be equal to either ground or to the power supply voltage, depending on which transistor is conducting.

When input A is grounded (logic 0) , the N-channel MOSFET is unbiased, and therefore has no channel enhanced within itself. It is an open circuit, and therefore leaves the output line disconnected from ground. At the same time, the P-channel MOSFET is forward biased, so it has a channel enhanced within itself. This channel has a resistance of about 200Ω, connecting the output line to the ＋V supply. This pulls the output up to ＋V (logic 1).

When input A is at ＋V (logic 1) , the P-channel MOSFET is off and the N-channel MOSFET is on, thus pulling the output down to ground (logic 0). Thus, this circuit correctly performs logic inversion, and at the same time provides active pull-up and pull-down, according to the output state.

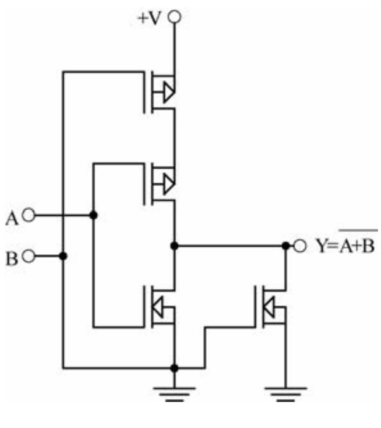


Fig. 3.2 CMOS NOR gate

This concept can be expanded into NOR and NAND structures by combining inverters in a partially series, partially parallel structure. The circuit shown in Fig. 3.2 is a practical example of a CMOS 2-input NOR gate.

In this circuit, if both inputs are low, both P-channel MOSFETs will be turned on, thus providing a connection to ＋V. Both N-channel MOSFETs will be off, so there will be no ground connection. However, if either input goes high, that P-channel MOSFET will turn off and disconnect the output from ＋V, while that N-channel MOSFET will turn on, thus grounding the output.

The structure can be inverted, as shown in Fig. 3.3. Here we have a two-input NAND gate, where a logic 0 at either input will force the output to logic 1, but it takes both inputs at logic 1 to allow the output to go to logic 0. [2]

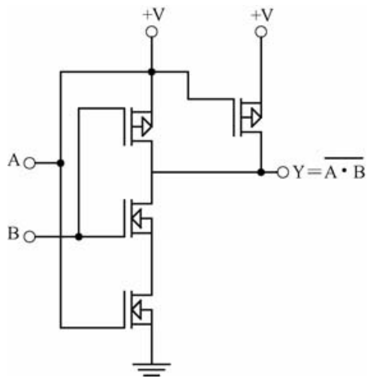


Fig.3.3　CMOS NAND gate

This structure is less limited than the bipolar equivalent would be, but there are still some practical limits. One of these is the combined resistance of the MOSFETs in series. As a result, CMOS totem poles are not made more than four inputs high. Gates with more than four inputs are built as cascading structures rather than single structures. However, the logic is still valid.

Even with this limit, the totem pole structure still causes some problems in certain applications. The pull-up and pull-down resistances at the output are never the same, and can change significantly as the inputs change state, even if the output does not change logic states. The result is uneven and unpredictable rise and fall times for the output signal. This problem was addressed, and was solved with the buffered, or B-series CMOS gates.

The technique here is to follow the actual NAND gate with a pair of inverters, as shown in Fig. 3.4. Thus, the output will always be driven by a single transistor, either P- channel or N-channel. Since they are as closely matched as possible, the output resistance of the gate will always be the same, and signal behavior is therefore more predictable.

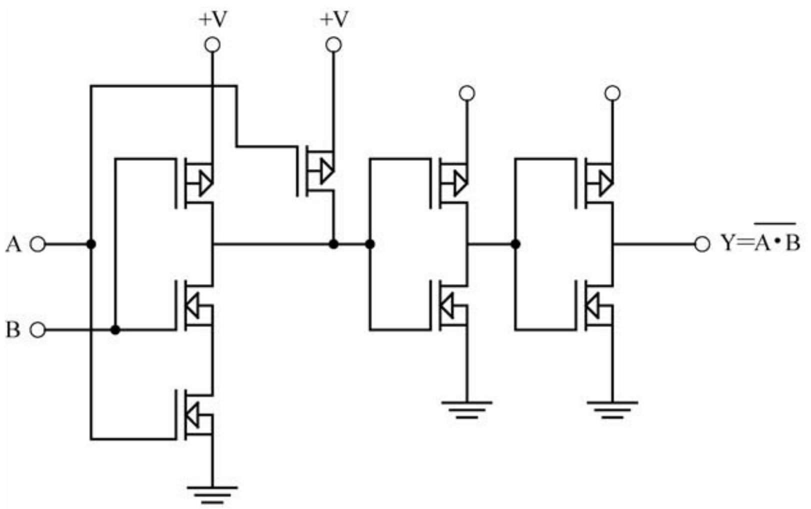


Fig. 3.4　CMOS NAND gate

One of the main problems with CMOS gates is their speed. They cannot operate very quickly, because of their inherent input capacitance. B-series devices help to overcome these limitations to some extent, by providing uniform output current, and by switching output states more rapidly, even if the input signals are changing more slowly.

Note that we haven't gone into all of the details of CMOS gate construction here. For example, to avoid damage caused by static electricity, different manufacturers developed a number of input protection circuits to prevent input voltages from becoming too high. [3] However, these protection circuits don't affect the logical behavior of the gates, so we won't go into the details here.

New Words and Phrases

1. CMOS	abbr.	(略语)互补金属氧化物半导体（complementary metallic oxide semiconductor）
2. logic [ˈlɔdʒik]	n.	逻辑，逻辑学，逻辑性，推理方法
3. complementary [kɔmpləˈmentəri]	adj.	补充的，补足的，互补的
4. battery-powered		电池供电的
5. gate [geit]	n.	门电路，逻辑门，闸门，控制栅，大门，通道，门口，入口
6. volt [vəult, vɔlt]	n.	[电]伏特，(马术中的)环骑，[击剑]闪避
7. fundamental [ˌfʌndəˈmentl]	adj.	基础的，基本的，主要的
	n.	基本原则，基本原理
8. enhancement- mode		增强型
9. MOSFET [ˈmɔsfet]	abbr.	(略语)金属氧化物半导体场效应晶体管 (metallic oxide semiconductor field effect transistor)
10. inverter [inˈvəːtə]	n.	反相器，反用换流器，变极器
11. source [sɔːs]	n.	来源，水源，消息来源，原始资料，发起者 [电]源，源极
12. drain [drein]	n.	排水沟，消耗，排水 [电]漏极
	vt.	排出，喝干，耗尽
	vi.	排水，流干，耗尽
13. matching [ˈmætʃiŋ]	adj.	相同的，相配的，匹配的
	n.	[计]匹配
14. effectively [iˈfektivli]	adv.	有效地，有力地，事实上，实际上
15. infinite [ˈinfinit]	n.	无限的东西(如空间) [数]无穷大
	adj.	无穷的, 无限的, 无数的, 极大的
16. grounded [ˈgraundid]		[计]接(好)地的
17. forward biased		正向偏置的，正偏的
18. NOR [nɔː](＝Not or)		[计]或非

19. NAND [nænd]	n.	[计]与非(门)
20. active [ˈæktiv]	adj.	积极的，活跃的，活性的，现行的，放射性的，有功的，有源的，带电的
21. pull-up		拉起动作，引体向上，[电]上拉
22. pull-down		[电]下拉
23. series [ˈsiəriːz]	n.	连续，系列，丛书，[电]串联，[数]级数
24. parallel [ˈpærəlel]	adj.	平行的，并列的，相同的，类似的，[电]并联的
	n.	平行线，平行面，类似，相似物
	vt.	平行于，匹敌
25. totem [ˈtəutəm]	n.	图腾，标识，徽章
26. totem pole		图腾柱
27. cascade [kæsˈkeid]	n.	小瀑布，喷流，层叠，[电]串联，级联
	vi.	成瀑布落下，级联
28. address [əˈdres]	n.	地址，致辞，演讲，技巧
	vt.	向……致辞，演说，处理，从事，忙于
29. buffer [ˈbʌfə]	n.	缓冲器，缓冲者，缓冲物，缓冲剂，[计]缓冲区
	vt.	缓冲
30. uniform [ˈjuːnifɔːm]	adj.	统一的，相同的，一致的，始终如一的，均衡的
	n.	制服，军服
31. valid [ˈvælid]	adj.	[律]有效的，有根据的，正当的，正确的
32. significantly [sigˈnifikəntli]	adv.	意味深长地，值得注目地
33. uneven [ˈʌniːvən]	adj.	不平坦的，不平均的，不均匀的，不一致的，奇数的
34. capacitance [kəˈpæsitəns]	n.	容量，电容
35. biased [ˈbaiəst]	adj.	有偏见的，偏置的，(统计试验中)结果偏倚的，[数]有偏的
36. resistance [riˈzistəns]	n.	反抗，抵抗，抵抗力，阻力，电阻，阻抗
37. inherent [inˈhiərənt]	adj.	固有的，内在的，天生的，与生俱来的

Notes

[1] CMOS logic is a newer technology, based on the use of complementary MOS transistors to perform logic functions with almost no current required.

CMOS 逻辑电路是一种基于互补 MOS 型晶体管来完成逻辑功能的新技术，这种晶体管几乎不需要电流。

句中的过去分词结构 based on…作定语，修饰表语 technology。

[2] Here we have a two-input NAND gate, where a logic 0 at either input will force the

output to logic 1, but it takes both inputs at logic 1 to allow the output to go to logic 0.

这是两输入的与非门，任一输入的逻辑 0 都会使输出为逻辑 1，但只有两个输入都为逻辑 1 才会使输出变为逻辑 0。

句中的 where 引导的是非限制性定语从句，修饰宾语 NAND gate。it 为形式主语，代替不定式短语 to allow…。

[3] For example, to avoid damage caused by static electricity, different manufacturers developed a number of input protection circuits to prevent input voltages from becoming too high.

例如，为了避免静电的损坏，各个制造商都开发了各种输入保护电路来防止输入电压变得过高。

句中的两个不定式短语 to avoid…和 to prevent…都作目的状语，过去分词短语 caused by static electricity 作定语，修饰 damage。

Translating Skills 词义的选择和引申

科技翻译崇尚“零感情”遣词，讲究译文的字斟句酌。因此善于结合科技文体的用词特点，准确了解同义词与近义词的词汇的内涵和外延，认真辨别词类，精确选择词义，根据语境恰当引申，在英汉互译的过程中，特别是英译汉过程中，就显得尤为重要。

科技文体的词汇特点

1. 科技英语频繁使用“技术词”(technical terms)、“半技术词”(semi-technical terms)

自动化专业有自动化专业术语的特定表达方式，在翻译过程中也有固定的翻译方法，不能任意发挥，出现不规范的翻译。如在电子技术中 resistor 表示电阻器，inductor 与汉语的电感器指同物，capacity 指电容器，triode 汉语意为三极管，diode 意指二极管。再如 thyristor(晶闸管)，rheostat(变阻)，flux(磁通)，shunt(并联，并励)，torque(转矩，扭矩)，baud 波特(发报速率单位)，quadrature(求面积，求积分)。同时也会使用很多的半技术词。半技术词在科技英语文体或一般英语文体中都会出现，出现的频率比前者高，有多义性，在不同的科技领域有其独特的不同涵义和译法，如 field(段，域)，lead(导线)，spring(弹簧)，relay(继电器)，variable(变化的，变量)。

2. 科技英语用词准确、客观、正式

在一般英语口语中会出现“Then the light is turned on.”这样的句子，而在书面科技文体中却会出现“The circuit is then completed.”这样的句子，两句意思一样，但 light 和 turn on 更口语化，circuit 和 complete 更正式。类似的例子很多，如：

A lot of people believe, however, that our progress depends on two different aspects of science.

然而，有**许多人**相信，我们的进步有赖于科学的两个不同方面。(该句是书面文体，因此口语化的英语短语 a lot of 应改为 many 更佳)

3. 频繁使用缩略词、合成词、符号、图表、公式，如:

UJT(unijunction transistor) 单结晶体管
fig.(figure) 3 图 3
E-mail(electronic mail) 电子邮件
Eq.(equation) 等式
UPS(uninterruptible power supply) 不间断电源
radar(radio detection and ranging) 雷达
SCR(silicon controlled rectifier) 可控硅
VSI(voltage-source inverters) 电压源逆变器
＝(is equal to,equals)等于
()(round brackets; parentheses)
∑(the summation of)
∫(integral of)
[illegible]$(t_0; \boldsymbol{x}_0, t_0) = \boldsymbol{x}_0$

词义选择

科技文章大多是就某一科学现象、客观规律、理论及其应用进行客观准确地阐述，在此过程中除了技术词词项单一，通过查字典、文献和询问专业人士外，有很多技术词或经常出现在一般文章中的词，它们有很多同义词和近义词，如果不根据上下文，很难确定该词的准确涵义，也就无法准确英汉互译，甚至会译出行外话，晦涩难懂，令人费解。因此准确选择词义是保证质量的关键。在翻译过程中注意以下几点。

1. 根据词在句中的位置，确定词类，选择词义

He **likes**(谓语，动词) mathematics more than physics.
他**喜欢**数学甚于喜欢物理。
The two girls are very **like** (表语，形容词) .
这两个女孩子很**相似**。
That was acting, the **like**(同位语，名词)of which we shall not see again.
我们再也看不到**那样好的演技**了。

2. 根据语境选择词义

语境即语言使用的具体环境，这里包括专业领域、上下文和文体风格。同一个词在不同的专业领域会有不同的词义，如 figure 在科技文章中指插图、附图。在逻辑学中指三段法的格。在数学中指数字符号，如 have a head of figure(数字概念强)。在几何学中指图形，如 plane figure(平面图形)，solid figure(立体图形)。在物理学中指系数，如 inductance figure(电感系数)，transistor noise figure(晶体管噪声系数)。在生活中指人物外形，如 the great figure of history(历史上的伟大人物)。在不同的上下文，单词的意义也大不相同。如：

Man's(人类)power to alter the nature of his world
men(男人)and woman

men(成年男子)and boys
officer and **men**(士兵)
man (丈夫)and wife
the chessboard and **men**(棋子)

3. 根据词的搭配关系选择词义

英汉两种语言在词语的使用上存在很大的差异，英语的搭配灵活多变，一个词可以搭配多个词，在汉译时要根据上下文及搭配关系，理解该词表达的不同内涵和外延意义，运用符合汉语习惯的表达方式，准确客观地译出；同时我们应该注意到，汉语中某一个词，在译成英语时也会有不同的搭配。

heavy electron 重电子	**heavy** current 强电流
heavy duty rectifier 大功率整流器	**heavy** gauge wire 粗导线
heavy fire 强烈射击	**heavy** news 悲惨的消息
心甘情愿 be most willing to	**心心**相印 have mutual affinity
民间协定 nongovernmental agreement	**民间**传说 popular legend
开玩笑 crack a joke	**开**支票 write a check
开刀 perform an operation	**开**夜车 work late into the night

4. 勤查词典，助选词义

在翻译的过程中，经常发现一些简单的词，或一些由常见的词合成的词，译者如果想当然地直接照译下去，有时会失之毫厘，谬以千里。如：

Textile finishes have in general become a **"no-no"**in today's market place…

(不能因为"no-no"看似简单就掉以轻心。其实如果查一查《英华大词典》词典，就会发现 no-no n.禁忌，禁例。)

翻译：织物整理剂在今日的市场已**禁**售。

词义引申

由于科技的飞速发展，每天都会有新词出现，词典收入出版新词的速度永远也赶不上科技发展的步伐，再者词典很难穷尽某个词所有的义项，因为每一个词在千变万化的上下文中会延伸出不同的涵义。这时就应该根据上下文和逻辑关系，进行恰当引申，翻译出既能准确传达原文信息又能符合汉语习惯的译文。

1. 根据所属专业，结合词典恰当引申

His rocket **harnesses**(动词义项有套上马具；套车→支配；控制→利用天然力；使产生动力)a nuclear process to produce a hot gas plasma.

他设计的火箭**能利用**核反应过程产生一种高温的气态等离子。

2. 根据译入语的习惯，利用上下文进行引申

A personnel **deficit**(赤字；亏损；逆差) has existed for years.

人员**短缺**的情况已经存在好多年了。

3. 将词义做具体化的引申

The transistor will do most of the **things**(事情；东西)a triode tube will do.
晶体管能起三极管所能起的大部分**作用**。

4. 将词义做抽象化的引申

Every life has its **roses**(玫瑰) and **thorns**(刺).
每个人的生活都有**甜**有**苦**。

Exercises

1. Translate the following into Chinese.

(1) Since only measurable parameters can be dealt with, the processing of the electrical signals the represent these parameters is composed solely of arithmetical or logical operation.

(2) For critical applications, the diode speed and reverse current leakage should be considered in addition to the maximum voltage and current, but otherwise the choice is arbitrary.

(3) A transistor in each of the three basic configurations (common base, CB; common emitter, CE; common collector, CC) is normally operated in the active region for the amplification of signals with minimum distortion.

(4) Around us all the time are hundreds of radio signals in the form of waves of energy.

(5) Something must be done to prevent the expanding outbreak of bird flu.

(6) The first round of the six-part talks had been colored by acrimony over North Korea's nuclear weapons.

(7) Two years’ working is a must to the people who want to take up graduated examination.

2. Translate the following into English.

(1) 与 TTL 电路相比，基于 CMOS 技术的逻辑门具有生产工艺简单和功耗低的优点，但工作速度相对慢一些。

(2) 门电路一般又称为逻辑电路，因为它们能够完成逻辑运算的功能，在实际设计中应用得十分广泛。

(3) 数字电路中的输入和输出信号只有两种状态，对应于数字逻辑中的 1 和 0。

(4) 只有一个输入的数字电路单元是缓冲器或反相器，而输入在一个以上的则称为逻辑门。

(5) 这位科学家早年为养家糊口曾干过兼职。

(6) 你建议用什么办法防止漏气?

(7) 这位司机迟早会断送性命的，因为他总违反交通规则。

Reading Material　Digital Logic Systems

The first clue is that we are talking about a special type of electrical circuit. This type of circuit is entirely constructed from a small number of different types of building block circuits.

Each of these circuits has one or more input connections and one output connection. The signals that we apply to the inputs and can be observed on outputs, with a test meter, have a special characteristic. The signals are always at one or the other of two voltage levels. To simplify matters we will think of these voltage levels as either high (voltage) or low (voltage). We call these signals logic signals and the circuits themselves logic circuits. As an alternative to call the signals high or low we can call them true or false respectively when we think of the circuits as logic circuits.

We call these circuits logic circuits because the theory that we use for describing them was invented by a mathematician who developed the mathematical theory of logic. The mathematician was George Boole who published his book “An Investigation of the Laws of Thought” in 1854. Boole’s concepts became a formal way of arguing about mathematical fundamentals. In the 1930’s, Claude Shannon realized the significance of this theory for the description of relay and switching circuits and wrote his thesis on the application of this concept to switching circuit design. His account of his thesis “A Symbolic Analysis of Relay and Switching Circuits”, Trans. A.I.E.E., vol 57, pp 713~723, was published in 1938 for the benefit of the engineering community. Shannon’s paper makes quaint but insightful reading with today’s hindsight. In those days, of course, telephone exchanges used mechanical relays, which was a major application for this development. The technology that we use now came along in 1948 when Brattain, Bardeen and Shockly at the Bell Telephone Laboratories published their invention of the transistor and not long after in 1959 when planar transistors were produced. This has started the revolution in integrated circuits that has accelerated the automation of information technology that we enjoy today. The theory that has developed, from Shannon’s original contribution, in the intervening years is just as applicable to today’s logic circuitry as it is for relay and switching circuits.

When a signal makes a transition from low to high or high to low, it does so very quickly. For this exposition we will ignore the fact that the signals actually have to pass through intermediate values in making a transition. Real circuits conform to this ideal very well indeed. So now we have arrived at the understanding that we have building block circuits in which all signals are either at the high (true) voltage level or the low (false) voltage level and can make near instantaneous transitions between the two levels.

The building block circuits with more than one input are called gates, whilst a building block circuit with only one input is a buffer or an inverter. We call the many input circuits gates because of the way they allow or prevent a signal from passing through. We will only consider 2-input gates but gates can have as many inputs as are needed. The buffer circuit simply boosts the driving power of a signal of whatever polarity without changing the polarity so that it can drive many more inputs to other circuits, whilst an inverter changes the signal level from whatever the input signal level is to the opposite signal level on its output. When we draw symbols for the circuits, we will represent the operation of inversion by a small circle usually on the output side of the symbol.

New Words and Phrases

1. clue [klu:]	n.	线索，暗示
	vt.	提供消息，为……提供线索，提示
2. building block		(儿童游戏用的)积木，构件，组成部件，程序块，标准部件
3. connection [kə'nekʃən]	n.	连接，关系，接线，线路，连接器，连接物，亲戚
4. apply to		关系到，牵涉到，适用于，运用于，向……询问，向……接洽，将……应用于
5. meter ['mi:tə]	n.	米，公尺，计，表，仪表
6. George Boole		布尔，乔治(1815—1864)英国数学家和逻辑学家，建立了一种符号逻辑
7. relay ['ri:lei]	n.	驿马，接替，继电器
	vt.	分程传递，使接替，转播
	vi.	得到接替，转播
8. thesis ['θi:sis]	n.	论题，论点，命题，论文，学位论文
9. quaint [kweint]	adj.	离奇的，有趣的，奇怪的，做得很精巧的，异常的，奇特的
10. insightful ['in,saitful]	adj.	有见识的，有眼光的，富于洞察力的，有悟性的
11. hindsight ['haindsait]	n.	枪的表尺，后瞄准器，后见之明，事后聪明
12. telephone exchange	n.	电话局，电话交换台
13. Brattain ['brætən]	n.	布拉顿(①姓氏 ②Walter Houser, 1902—1987，美国物理学家，曾获 1956 年诺贝尔物理学奖)
14. Bardeen [bɑ:'di:n]	n.	巴丁(1908—1991)美国物理学家。在 1956 年他因发展了电子晶体管而获诺贝尔奖，1972 年他因提出了超导理论再次获此殊荣
15. planar ['pleinə]	adj.	平面的，平坦的，二维的，二度的
16. transition [træn'ziʒən, -'siʃən]	n.	转变，转换，跃迁，过渡，变调，临界点，转折点，平移
17. whilst [wailst]	adv. , conj.	当……时候，有时，时时
18. exposition [ˌekspə'ziʃən]	n.	博览会，展览会，说明，阐明，曝露 [戏]展示部分，[音]呈示部
19. instantaneous [ˌinstən'teinjəs]	adj.	瞬间的，即刻的，即时的，猝然的
20. polarity [pəu'læriti]	n.	极性，磁性，偏光性，配极，性格 [主义，行动]正相反，倾向

Lesson 4 Flip-Flop

Latch and flip-flop are memory elements which are used in switching circuits. A latch is a memory element whose excitation input signals control the state of the device. [1] If a latch has an excitation input signal that force the output of the device to 1, it is called a set latch. If it has an excitation input signal that forces the device output to 0, it is called a reset latch. If the device has both set and reset excitation signals, it is called a set-reset latch. A Flip-Flop differs from a latch is that it has a control signal called a clock. The clock signal issues a command to the flip-flop, allowing it to change states in accordance with its excitation input signals. The most basic types of Flip-Flop operate with signal levels and are referred to as latches.

Basic SR Flip-Flop. Basic SR Flip-Flop (SR latch) is often called SR latch. The SR Flip-Flop is a circuit with two cross-coupled NOR gates or two cross-coupled NAND gates. It has two inputs-S for set, R for reset. The **SR Flip-Flop** is shown in Fig. 4.1. It is constructed with two cross-coupled NOR gates.

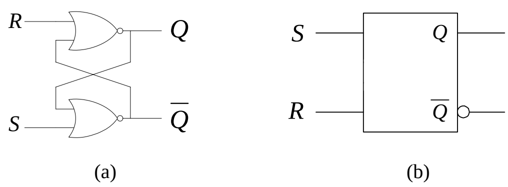


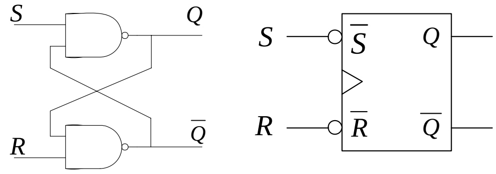
Fig.4.1 The SR Flip-Flop

When input S=1 and R=0,the output Q=1, $\overline{Q}$=0, it is referred to be in the set state. When input R=1 and S=0,the output Q=0, $\overline{Q}$=1, it is in the reset state. When both inputs are equal to 0, the Flip-Flop can be in either the set or the reset state, depend on which input was most recently at 1. [2]When both inputs are equal to 1, output is in the undefined state because it results in an unpredictable next state when both inputs return to 0. Output Q and $\overline{Q}$ are normally the complement of each other. The truth table is shown in Table 4−1.

Table 4−1 SR Flip-Flop function table

S	R	Q^n	Q^{n+1}
1	0	1	1
1	1	0	1
0	1	0	0
0	1	1	0
0	0	0	0
0	0	1	1
1	1	0	0^*
1	1	1	0^*
0^* is undefined state			

The SR Flip-Flop with two cross-coupled NAND gates is shown in Fig. 4.2. It operates with both inputs normally at 1 unless the state of the Flip-Flop has to be changed. [3]The application of 0 to the *S* input causes output *Q* to go to 1, putting the Flip-Flop in the set state. When the *S* input goes back to 1, the circuit remains in the set state. After both inputs go back to 1, we are allowed to change the state of the Flip-Flop by placing a 0 in the *R* input. This causes the circuit to go to the reset state and stay there even after both inputs return to 1.The condition that is undefined for the NAND Flip-Flop is when both inputs are equal to 0 at the same time. The function table is shown in Table 4−2.



(a)　(b)

Fig. 4.2　Logic diagram

Table 4−2　Function table

S	*R*	Q^n	Q^{n+1}	*S*	*R*	Q^n	Q^{n+1}
1	1	0	0	1	0	0	0
1	1	1	1	1	0	1	0
0	1	0	1	0	0	0	1^*
0	1	1	1	0	0	1	1^*

1^* is undefined state

Synchronous SR Flip-Flops. The operation of the basic SR Flip-Flop can be modified by providing an additional control input that determines when the state of the Flip-Flop can be changed. The SR Flip-Flop with a control input is referred as synchronous SR Flip-Flop which is shown in Fig. 4.3. It consists of the basic SR flip-flop and two additional NAND gates. The control input *CP* acts as an enable signal for the other two inputs. The output of the NAND gates stays at the logic 1 level as long as the control input remains at 0. This is the quiescent condition for the basic SR Flip-Flop. When the control input goes to 1, information from the *S* or *R* input is allowed to affect the basic SR Flip-Flop. The reset state is reached with *R*=1, *S*=0 and *CP*=1.To get to the set state, the input must be *R*=0, *S*=1 and *CP*=1.When *CP* returns to 0, the control input disables, so that the state of the output does not change regardless of the value of S and R. Moreover, when *CP*=1 and both the *S* and R inputs are equal to 0, the state of the circuit does not change. The function table is presented in Table 4−3.

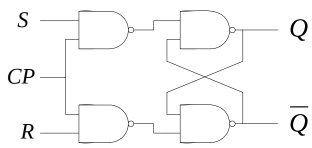


Fig. 4.3　Logic diagram

Table 4−3 Function table

CP	*S*	*R*	Q^n	Q^{n+1}
0	×	×	0	0
0	×	×	1	1
1	0	0	0	0
1	0	0	1	1
1	1	0	0	1
1	1	0	1	1
1	0	1	0	0
1	0	1	1	0
1	1	1	0	1^*
1	1	1	1	1^*
1^* is undefined state				

There are undefined states when all three inputs are equal to 1, it makes this circuit difficult to manage and it is seldom used in practice. Nevertheless, it is an important circuit because other latches and Flip-Flops are constructed from it.

Master-Slave SR Flip-Flops. One method to prevent the unstable behavior just described is to use two latches in a master-slave configuration, as shown in Fig. 4.4.The enable signals of the two latches are driven by complementary versions of a clock signal. When the clock signal *CP* is high, the master Flip-Flop is in the gated mode and the slave Flip-Flop is in the hold mode. When the clock changes to logic 0 the two Flip-Flops exchange roles. The slave Flip-Flop enters the gated mode, sending the output of the master Flip-Flop to the Flip-Flop output *Q*, while the master Flip-Flop enters the hold mode and ignores any further changes on its inputs. Function table for the master-slave SR Flip-Flop is presented in Table 4−4.

Table 4−4 Function table

CP	*S*	*R*	Q^n	Q^{n+1}
×	×	×	×	Q^n
$\sqcap\downarrow$	0	0	0	0
$\sqcap\downarrow$	0	0	1	1
$\sqcap\downarrow$	0	1	0	0
$\sqcap\downarrow$	0	1	1	0
$\sqcap\downarrow$	1	0	0	1
$\sqcap\downarrow$	1	0	1	1
$\sqcap\downarrow$	1	1	0	1*
$\sqcap\downarrow$	1	1	1	1*
1^* is undefined state				

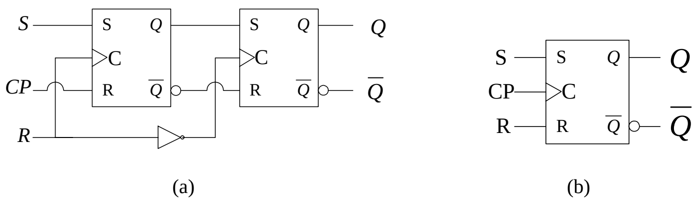


Fig.4.4 Logic diagram

Master-slave JK Flip-Flops. We hope the state for the master-slave SR Flip-Flop is defined When *S*=*R*=1, so we improve the configuration in master-slave SR Flip-Flop. The outputs Q and $\overline{Q}$ are connected back to the input as a pair of additional control signal. Substitute *J, K* for *S, R* in the circuit. The Flip-Flop is referred as JK Flip-Flop. In a word, the JK Flip-Flop may be considered as an extension of the master-slave SR Flip-Flop.

The feature of the JK device is that its state toggles, that is, changes from 0→1 or form 1→0, When *J*=*K*=1, the four modes of operation (hold, set, reset and toggle) are summarized in the function table presented in Table 4−5.

Table 4−5 Function table

CP	J	K	Q^n	Q^{n+1}
×	×	×	×	Q^n
	0	0	0	0
	0	0	1	1
	1	0	0	1
	1	0	0	1
	0	1	0	0
	0	1	1	0
	1	1	0	1
	1	1	1	0

1* is undefined state

New Words and Phrases

1. latch [lætʃ]	n.	插销，撞锁，弹簧锁；锁存器
	vt., vi.	插上插销
2. Flip-Flop	n.	双稳态多谐振荡器，触发器
3. switching circuit		开关电路
4. unpredictable［ˈʌnpriˈdiktəbl］	adj.	不可预知的
5. complement [ˈkɔmplimənt]	n.	补足物，补语，余角，余数；补数，补码；反码
	vt.	补助，补足
6. truth table		(逻辑运算)真值表

7. quiescent［kwai'esənt］ adj. 静止的
8. unstable［'ʌn'steibl］ adj. 不牢固的，不稳定的
9. synchronous ['siŋkrənəs] adj. 同时的，同期的 [物]同步的
10. CP abbr. (略语)时钟脉冲(Clock Pulse)
11. version ['vəːʃən] n. 样式，形式，译文，译本，翻译
12. toggle ['tɔgl] n. 触发器，乒乓开关；轮转，(来回)切换
vt. 拴牢
13. toggle Flip-Flop 反转触发器
14. in accordance with 与……一致, 依照
15. disable [dis'eibl] vt. 使无能，禁止，使失效
16. regardless of 不管，不注意，与……无关
17. gated 门控，选通

Notes

[1] A latch is a memory element whose excitation input signals control the state of the device.

锁存器是由输入信号控制器件输出状态的存储元件。

句中 whose 引导的定语从句修饰 memory element。

[2] When both inputs are equal to 0, the Flip-Flop can be in either the set or the reset state, depend on which input was most recently a 1.

输入都为 0 时, 触发器或者为置位状态，或者为复位状态，这主要取决于哪个输入端被最后置为 1。

句中 which 引导的为非限定性定语从句，修饰前面的整个主句。

[3] It operates with both inputs normally at 1 unless the state of the Flip-Flop has to be changed.

触发器的两个输入通常都为 1，除非其状态需要改变。

句中 unless 引导条件状语从句。

Translating Skills 常见多功能词的译法

这里要讲的多功能词指的是词的多功能性，它有两方面的含义。一是指一词多类，二是指一词多义。所谓一词多类，就是指一个词可以有不同词类。如 design 在 program design(程序编制)、functional design(实际结构)中作名词，在 design a better timetable(想出一个更好的时间表) 、design a experiment(规划试验)中作动词。而一词多义是指一个词在同一个词类中有多个不同的词义。还以 design 为例，当该词作名词时，可以表示“设计”、“造型”、“式样”、“图案”、“结构”、“型别”、“机械结构”、“设备”、“机件”、“电路结构”、“电路方案”、“故意”、“不良企图”等意义。词的功能性指某种词类进入句法结构以后充当的句法成分，如主语、谓语、宾语、定语、状语和补语等。不同词类在

句中所作的句子成分也不一样。同一种词类在句中既可以作这种成分也可以作那种成分，具有多功能性。例如在英语中，名词既可作主语也可作宾语(直接宾语或间接宾语)，还可作定语、介词的宾语；形容词可作定语，某些形容词前面加上定冠词 the 表示一类人或物，可做主语等。在汉语里，形容词不只作定语，它还可以作谓语、状语、甚至主语、宾语等。由于英汉两种语言同一词类在句子的语法结构中充当的成分有差异，同一词的表达习惯，词的所指意义不同，因此在英汉互译的过程中，应根据其所在的上下文和在语法结构中的功能进行翻译。

英语中常见一词多义和一词多类的词的翻译。

一个词的多义和多类常常紧密相连，通常情况下某个词既是多义词又是多类词。再者由于英汉表达习惯的差异，英语中的一个多义词和汉语中相当的一个多义词是不能完全对等的，其含义在内涵和外延上会有所不同。体现在翻译上，表达也会随着发生变化。如英语句中的一个词翻译成汉语时，需要增译，用汉语的短语表达。反之，汉语中的一个词在英语中的表达也不同，可能要省译，翻译成单个的词；也可能要增译，翻译成几个词一起来表达该义。总之，“译词要有原则，必须恪守原语词义，做到义切形切，在形切难以达到时，必须做到义切。”(刘宓庆《汉英对比翻译》)。具体情况要结合专业知识、上下文、在句中的语法成分，认真分析，准确把握。这里分别从英汉互译的角度，挑选科技英语中经常遇到的一些一词多义和一词多类的词进行分析，以期对多功能词的翻译有所启发。

1. Power(一词多义)

(1) It’s beyond my **power** to help the poor girl.(不可数名词，意指“能力”，与介词一起作表语，生活用语)

我没有**能力**帮助这个小女孩。

(2) You are taxing your **power** too much. (不可数名词，意指“精力”，作宾语，生活用语)

你在耗费太多的**精力**。

(3) Congress has **power** to declare war. (不可数名词，作宾语，意指“权力”，政治用语)

国会有**权**宣战。

(4) Is the press a great **power** in your country? (可数名词，意指“很有影响力的组织”，作表语，社会用语)

贵国的报界有很大的**影响力**吗？

(5) Typically, these sources can only provide currents of a few milliamps, which by $P=VI$ means **powers** of just a few milliwatts. (可数名词，意指“功率”，在定语从句中作宾语，物理用语。类似用法如 overall power 总功率，power transistor 功率晶体管)

典型情况下，这些信号源只能提供数毫安的电流，根据 $P=VI$，信号源的**功率**只有几毫瓦。

(6) 16 is the fourth **power** of 2. (可数名词，意指“乘方，幂”，作表语，数学用语)

二的四次**幂**等于十六。

(7) This is a newly-built **power**-house. (名词，与 house 构成复合名词，作宾语，意指“动力”，电力用语)

这是一个新建的**发电**所。

2. Charge(一词多义和一词多类)

(8) How much do you **charge** for a haircut？(及物动词，意指“要价，索价，收费”，作谓语，生活用语)

你剪一个头**要**多少钱？

(9)The bomb was **charged** with dynamite. (及物动词，意指“装满”，作谓语，军事用语)

炸弹里**装满**了炸药。

(10) The children **charged** out of the school. (不及物动词，意指“向前冲”，作谓语，学校用语)

孩子们**冲**出学校。

(11) The judge **charged** him not to reveal the source of information. (及物动词，意指“命令，指示”，作谓语，法律用语)

法官**指示**他不许泄露消息的来源。

(12)Electrons **are** negatively **charged** with electricity; protons **are** positively **charged**. (及物动词，意指“充电于”，作谓语，化学用语)

电子是带负**电荷**；质子是带正**电荷**。

(13) Like **charges** repel; unlike **charges** attract. (名词，意指“电荷”，作主语，化学用语)

相同的**电荷**相斥，不同的**电荷**相吸。

(14) He was arrested on a **charge** of theft.(名词，意指“指控，控告”，作介词的宾语，法律用语)

他因盗窃的**罪名**而被捕。

3. Sink(一词多义和一词多类)

(15) She complains that she spends half her life at the kitchen **sink.** (名词，作介词的宾语，意指“洗涤槽”)

她埋怨作了半辈子的**家务**。

(16) The sun was **sinking** in the west. (动词，作谓语，意指“沉下，沉落”)

太阳正在西方沉落。

(17) These men were **sinking** a well. (动词，作谓语，意指“挖，掘”)

这些人正在**挖**井。

(18) He has **sunk** half his fortune in a new business undertaking. (动词，作谓语，意指“投资”)

他已**把**一半财产**投资**于一新的企业中。

4. Access

(19) Random **access** procedures are well matched to the needs of bursting users since the entire bandwidth of a channel can be used by a station once it successfully **accesses**.

随机**访问**规程最适合于突发性用户的需要，因为一旦某一网站成功地**上网**，他就可占用信道的全部带宽。(第一个“access”是名词，意指“通路”，作主语中心词“procedures”

的定语；第二个“access”是动词，作“once”引导的从句的谓语，意指“进入”，计算机用语)

(20) Carrier-sense multiple **access** protocols are refinements on the pure and slotted ALOHA protocols.

载波侦听多点**访问**协议是对纯 ALOHA 和时隙 ALOHA 协议的改进。(名词，意指“通路”，作主语中心词“protocols”的定语)

(21) The old expert is a man of easy **access**.

这位老专家**平易近人**。(名词，意指“接近”，作介词的宾语，构成介词短语，作后置定语，修饰句中的表语，生活用语)

(22) Today, most people had **access** to education in china.

今天的大多数人都有**机会**接受教育。(名词，意指“机会”，作宾语，社会用语)

汉语中常见“一词多译”的词翻译。

5. 精通

(23) He is well **versed** in painting.

他在画画方面很**精通**。

(24) The worker **is practised in** repairing .

这个工人**精通**修理。

(25) The old man **is well read in** Shakespeare’s works.

这位老者**精通**莎翁的作品。

(26) The young woman **is skilled in** making lace.

这个年轻妇女**精通**做花边。

6. 扩大，增大

(27) His father **enlarged** his house by adding a new wing.

他的父亲通过加一个侧厅将房子**扩大**了。

(28) Your company should **increase** a sales force.

你们公司应该**扩大**推销员小组。

(29) This instrument can **amplify** radio signals.

这种仪器能**增强**无线电信号。

Exercises

1. Translate the following into Chinese.

(1) With voltage of a specific value applied between the anode and a selected cathode, a characteristic orange glow appears around the appropriate cathode. This glow is a result of neon gas ionization within the display enclosure.

(2) Seven-segment LED display devices often contain four or more discrete diodes connected in parallel to form a segment.

(3) The electronic processes involved in producing a particular display include the

ionization of a gas and powering incandescent elements, light-emitting diodes, and liquid- crystal display elements.

(4) Power is provided by a 40-kilowatt generator mounted on the truck.

(5) Power is provided by a motor-generator set.

(6) Mould temperature is controlled by water flow in cooling channels.

2. Translate the following into English.

(1) 如果网络中不包含电池或发电机等能源，就称为无源网络。

(2) 当二极管反向偏置时，在达到反向击穿电压前，其中只有很小的漏电流通过。

(3) 有源开关设备工作于零电流切换状态，因此具有极高的转换效率与非常低的射频干扰辐射。

(4) 你们的情况怎么样？

(5) 在这种情况下，你可以给他打电话。

(6) 这种情况已经改变了。

Reading Material　Digital System Display

As a general rule, the average person called on to read the output of a digital system will not be familiar with the BCD method of displaying numbers. Digital systems must therefore change this information into a suitable method of display in order to be practical. Alphanumeric displays are commonly used today to achieve this operation. These devices can be used to display both number and letter information. In this case we are only concerned with the display of numerical information.

Three common methods of displaying numerical information are available today. This includes the discrete number method, bar matrix displays, and the dot matrix. Each method represents a unique device designed to change electrical energy into light energy. The basic characteristics of the device dictate such things as operating voltage, current, illumination level, and quality of the display character.

The three basic methods of digital display are shown in Fig. 4.5. Each display produces a particular type of character that is easily recognized. The electronic processes involved in producing a particular display include the ionization of a gas and powering incandescent elements, light-emitting diodes, and liquid-crystal display elements. Each method of display has a number of features and characteristics that must be taken into consideration when selecting a device for a specific application.

Gaseous Display Devices

The gaseous display tube has been used for a number of years as a digital readout device. The construction of this device includes a common anode and multiple cathodes shaped as discrete numbers or segmented bars. The numbers, or bar segments, remain somewhat transparent until energized electrically. With voltage of a specific value applied between the anode and a selected cathode, a characteristic orange glow appears around the appropriate cathode. This glow is a result of neon gas ionization within the display enclosure.

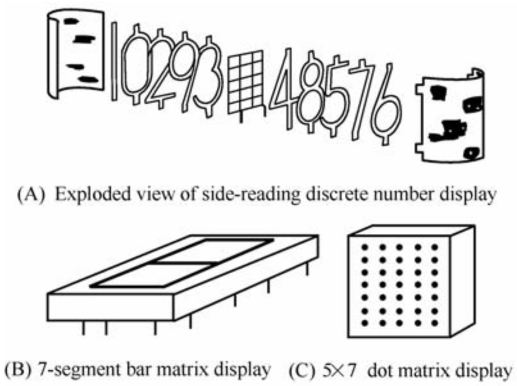


Fig.4.5 Digital display methods

Fig. 4.6 shows two types of gaseous display devices and their corresponding electrical circuits. In the discrete number display (Fig.4.6(A)), each switch completes an electrical circuit between the anode and a selected cathode. A dc source voltage of 170V or more is needed to ionize the neon gas in this device to make it operate. The switching action that controls operation is normally achieved by a decoder IC. This device simply completes a return path to ground when the appropriate number is needed is a display.

The operation of a seven-segment gaseous display device (Fig.4.6(B)) is very similar to that of the discrete number unit just discussed. The method of display, however, is somewhat different. It is achieved by energizing a combination of two or more discrete segments. The number 8, for example, is displayed when all segments are energized. The number 0 is displayed when all segments are energized except the center. The segmented bars of this display are labeled a, b, c, d, e, f, and g, respectively, and positioned to form a box 8 number.

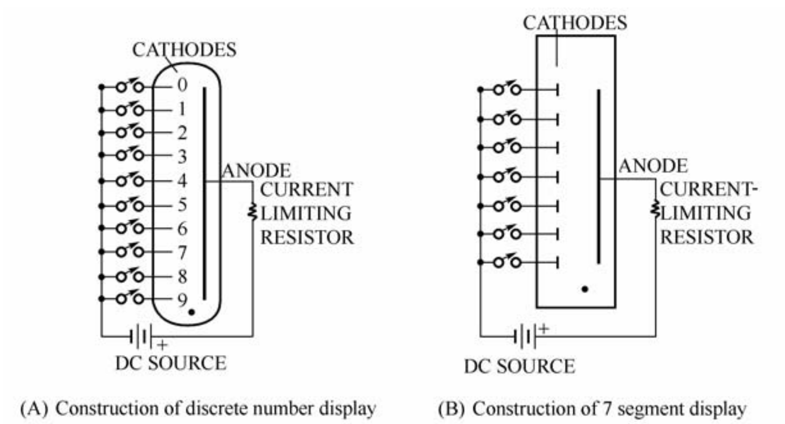


Fig. 4.6 Gaseous display devices

Incandescent Display

Seven-segment incandescent display devices are used in some industrial digital systems today. These display units contain seven discrete resistive elements suspended between supporting posts. One side of each element is connected to a common tie point. Illumination occurs when current flows through a specific element and the common point. Usually, 5 V of ac or dc electricity is needed to produce a desired degree of illumination. Display devices of this type are commonly called Numitrons. RCA is the principal manufacturer of this device today.

Fig. 4.7 shows an electrical circuit of a DR2000 Numitron. Note that this display produces a block type of seven-segment number similar to that of the gaseous display device. The chief advantage of the Numitron is its variable intensity characteristic. The filament segments of this device are, however, somewhat fragile when they are energized.

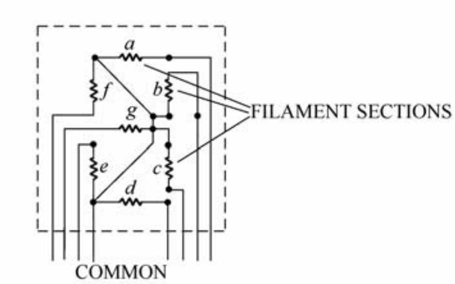


Fig. 4.7　Electrical diagram of Numitron display device

When a discrete segment of a Numitron is electrically energized, heat occurs. If enough heat is developed, the filament wire changes to a dull orange appearance and produces light energy. The degree of illumination produced is quite evident when compared with an unexercised element. As a result, this noticeable change is used to indicate segment illumination.

The discrete filament segments of a Numitron are commonly connected to form a single tie point. This essentially means that each filament presents a parallel path for the current from the source. As a result of this construction, filament current increases a set amount when each segment is energized. The number 8 therefore demands the largest amount of current from the source when it is displayed.

The circuitry of a Numitron is somewhat simplified when compared with other seven-segment display devices. For example, it does not necessitate a current-limiting resistor. This resistance is built in or self-contained in each filament element. The common tie point is typically connected to the positive side of the source, and each segment is energized by connecting its other side to ground.

Light-emitting Diode Displays

Light-emitting diodes are commonly used in seven-segment and 5×7 dot matrix displays. The LEDs of these devices produce visible light when forward biased and no light when reverse biased. As a result of this two-state condition, discrete segments or dots can be illuminated when diodes are energized. Typically, the positive side of the energy source is applied to the anodes of each diode through a current-limiting resistor. The cathode of a respective diode is then grounded by switching action. When the circuit is complete, the diode is energized, thus producing light.

Seven-segment LED display devices often contain four or more discrete diodes connected in parallel to form a segment. This type of construction usually necessitates only one current-limiting resistor for each segment. The amount of voltage needed to produce illumination is typically 3.5 to 5 V dc.

Fig. 4.8 shows the circuitry of seven-segment and 5×7 dot matrix LED display devices. The LEDs in both circuits are similar in all respects. The switching method needed to energize specific diodes is somewhat special. In the seven-segment device (Fig. 4.8(B)), each segment is controlled by a single switch. The dot matrix circuit (Fig. 4.8 (D)), by comparison, is controlled by two or more switches. A discrete diode can be energized by two switches such as row 4, column 5. A complete vertical row would require one column switch and all seven row switches. A complete horizontal row would be energized by one row switch and all five column switches. As a general rule, dot matrix display devices are used to produce letter displays more than numbers. LED display devices are used more frequently in industrial applications today than all other devices combined.

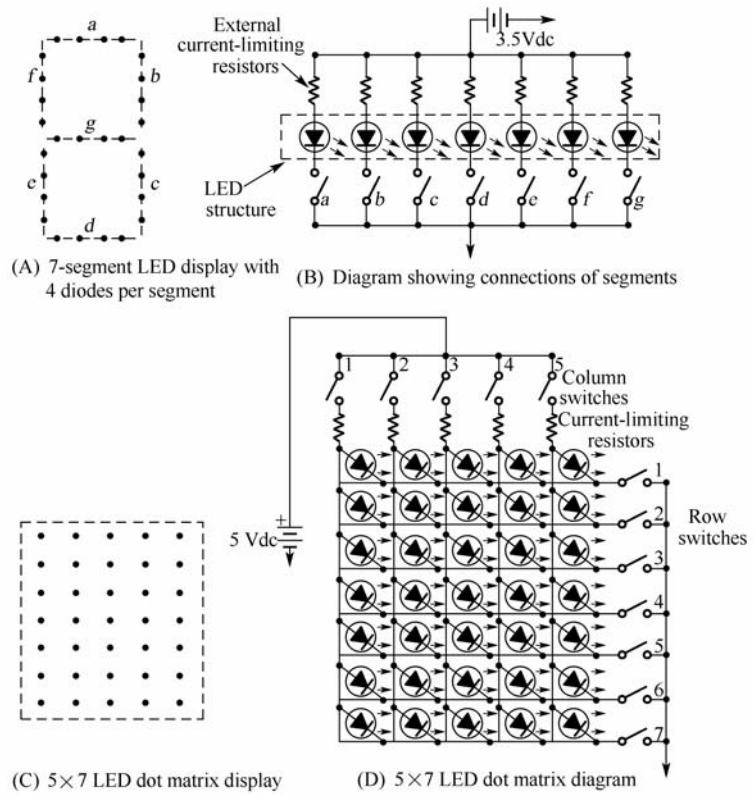


Fig. 4.8 LED display device

Liquid-crystal display units represent a fourth major classification of display devices. This method of display is achieved by applying electrical energy in the form of voltage to discrete bars of phosphorizing silicon. When voltage is applied, the crystal material changes from a transparent state to an opaque condition that reflects ambient light. In a strict sense, this action takes place when the phosphors are bombarded by electrons from the energy source.

Liquid-crystal Display

Liquid-crystal digital display devices are typically of the seven-segment type. The circuit construction is very similar to that of the seven-segment LED display of Fig. 4.8. Each segmented bar responds as an LED when energized. As a general rule, liquid-crystal displays are commonly used in wristwatches, pocket calculators and portable digital devices. Very small amounts of electrical energy are needed to produce a significant readout display.

Liquid-crystal displays are primarily designed to reflect normal room light when they are energized. This type of display therefore develops significantly less light intensity when compared with other displays. Liquid-crystal units are rarely even used in industrial applications today because of this deficiency.

New Words and Phrases

1. alphanumeric [ˌælfənjuːˈmerik]	adj.	文字数字的，字母数字的，包括文字与数字的
2. matrix [ˈmeitriks]	n.	矩阵
3. illumination [iˌljuːmiˈneiʃən]	n.	照明，阐明，启发，灯饰(通常用复数)
4. ionization ［ˌaiənaiˈzeiʃən]	n.	电离
5. incandescent ［ˌinkænˈdesnt]	adj.	遇热发光的, 白炽的
6. gaseous [ˈgæsiəs, ˈgeizjəs]	adj.	气体的，气态的；瓦斯的；不具体的，不可靠的
7. discrete [diˈskriːt]	adj.	离散的；分立的；分离的，不连续的
8. readout [ˈriːdaut]	n.	读数装置，读出，读数
9. anode [ˈænəud]	n.	阳极，正极，极板，氧化极
10. cathode [ˈkæθəud]	n.	阴极，负极(亦作 negative pole)
11. intensity [inˈtensiti]	n.	强烈，剧烈，强度，亮度
12. filament [ˈfiləmənt]	n.	细丝，灯丝
13. fragile ［ˈfrædʒail]	adj.	易碎的，脆的
14. parallel ［ˈpærəlel]	adj.	平行的
15. neon [ˈniːən]	n.	[化]氖
16. ionize [ˈaiənaiz]	vt.	使离子化
	vi.	电离
17. segment [ˈsegmənt]	n.	段，片，部分，节，线段，弓形，弧形，球缺；整流子片；程序段

18. transparent［træns'pεərənt］	adj.	透明的，显然的
19. opaque [əu'peik］	adj.	不透明的，
20. energize ['enədʒaiz]	vt.	使活跃，加强，给与……电压
21. tie point		集接点，连接点
22. bombard ['bɔmbɑːd］	vt.	轰击
23. vertical［'vəːtikəl］	adj.	垂直的
24. horizontal［ˌhɔri'zɔntl］	adj.	水平的
25. phosphorize［'fɔsfəraiz］	v.	加磷，使发出磷光

Lesson 5 Introductions to Control Systems

Automatic control has played a vital role in the advancement of engineering and science. In addition to its extreme importance in space-vehicle, missile-guidance, and aircraft-piloting systems, etc, automatic control has become an important and integral part of modern manufacturing and industrial processes. For example, automatic control is essential in such industrial operations as controlling pressure, temperature, humidity, viscosity, and flow in the process industries; tooling, handling, and assembling mechanical parts in the manufacturing industries, among many others.

Since advances in the theory and practice of automatic control provide means for attaining optimal performance of dynamic systems, improve the quality and lower the cost of production, expand the production rate, relieve the drudgery of many routine, repetitive manual operations etc, most engineers and scientists must now have a good understanding of this field.

The first significant work in automatic control was James Watt's centrifugal governor for the speed control of a steam engine in the eighteenth century. Other significant works in the early stages of development of control theory were due to Minorsky, Hazen, and Nyquist, among many others. In 1922 Minorsky worked on automatic controllers for steering ships and showed how stability could be determined by the differential equations describing the system. In 1934 Hazen, who introduced the term "servomechanisms" for position control systems, discussed design of relay servomechanisms capable of closely following a changing input.

During the decade of the 1940's, frequency-response methods made it possible for engineers to design linear feedback control systems that satisfied performance requirements. From the end of the 1940's to early 1950's, the root-locus method in control system design was fully developed.

The frequency-response and the root-locus methods, which are the core of classical theory, lead to systems that are stable and satisfy a set of more or less arbitrary performance requirements. Such systems are, in general, not optimal in any meaningful sense. Since the late 1950's, the emphasis on control design problems has been shifted from the design of one of many systems that can work to the design of one optimal system in some meaningful sense.

As modern plants with many inputs and outputs become more and more complex, the description of a modern control system requires a large number of equations. Classical control theory, which deals only with single-input-single-output systems, becomes entirely powerless for multiple-input-multiple-output systems. Since about 1960, modern control theory has been developed to cope with the increased complexity of modern plants and the stringent requirements on accuracy, weight, and industrial applications.

Because of the readily available electronic analog, digital, and hybrid computers for use in complex computations, the use of computers in the design of control systems and the use of on-line computers in the operation of control systems are now becoming common practice.

The most recent developments in modern control theory may be said to be in the direction of the optimal control of both deterministic and stochastic systems as well as the adaptive and learning control of complex systems. Applications of modern control theory to such nonengineering fields as biology, economics, medicine, and sociology are now under way, and interesting and significant results can be expected in the near future.

Next we shall introduce the terminology necessary to describe control systems.

Plants. A plant is a piece of equipment, perhaps just a set of machine parts functioning together, the purpose of which is to perform a particular operation. Here we shall call any physical object to be controlled (such as a heating furnace, a chemical reactor, or a spacecraft) a plant.

Processes. The Merriam-Webster Dictionary defines a process to be a natural, progressively continuing operation or development marked by a series of gradual changes that succeed one another in a relatively fixed way and lead toward a particular result or end; or an artificial or voluntary, progressively continuing operation that consists of a series of controlled actions or movements systematically directed toward a particular result or end. [1] Here we shall call any operation to be controlled a process. Examples are chemical, economic, and biological process.

Systems. A system is a combination of components that act together and perform a certain objective. A system is not limited to abstract, dynamic phenomena such as those encountered in economics. The word “system” should, therefore, be interpreted to imply physical, biological, economic, etc., system.

Disturbances. A disturbance is a signal which tends to adversely affect the value of the output of a system. If a disturbance is generated within the system, it is called internal, while an external disturbance is generated outside the system and is an input.

Feedback control. Feedback control is an operation which, in the presence of disturbances, tends to reduce the difference between the output of a system and the reference input (or an arbitrarily varied, desired state) and which does so on the basis of this difference. Here, only unpredictable disturbance (i.e., those unknown beforehand) are designated for as such, since with predictable or known disturbances, it is always possible to include compensation with the system so that measurements are unnecessary.

Feedback control systems. A feedback control system is one which tends to maintain a prescribed relationship between the output and the reference input by comparing these and using the difference as a means of control. [2]

Note that feedback control systems are not limited to the field of engineering but can be found in various nonengineering fields such as economics and biology. For example, the human organism, in one aspect, is analogous to an intricate chemical plant with an enormous variety of unit operations. The process control of this transport and chemical-reaction network involves a variety of control loops. In fact, human organism is an extremely complex feedback control system.

Servomechanisms. A servomechanism is a feedback control system in which the output is some mechanical position, velocity, or acceleration. Therefore, the terms servomechanism and position- (or velocity- or acceleration-) control system are synonymous. Servomechanisms are extensively used in modern industry. For example, the completely automatic operation of machine tools, together with programmed instruction, may be accomplished by use of servomechanisms.

Automatic regulating systems. An automatic regulating system is a feedback control system in which the reference input or the desired output is either constant or slowly varying with time and in which the primary task is to maintain the actual output at the desired value in the presence of disturbances. [3]

A home heating system in which a thermostat is the controller is an example of an automatic regulating system. In this system, the thermostat setting (the desired temperature) is compared with the actual room temperature. A change in the desired room temperature is a disturbance in this system. The objective is to maintain the desired room temperature despite changes in outdoor temperature. There are many other examples of automatic regulating systems, some of which are the automatic control of pressure and of electric quantities such as voltage, current and frequency.

Process control systems. An automatic regulating system in which the output is a variable such as temperature, pressure, flow, liquid level, or pH is called a process control system. [4] Process control is widely applied in industry. Programmed controls such as the temperature control of heating furnaces in which the furnace temperature is controlled according to a preset program are often used in such systems. For example, a preset program may be such that the furnace temperature is raised to a given temperature in a given time interval and then lowered to another given temperature in some other given time interval. [5] In such program control the set point is varied according to the preset time schedule. The controller then functions to maintain the furnace temperature close to the varying set point. It should be noted that most process control systems include servomechanisms as an integral part.

New Words and Phrases

1. viscosity [visˈkɔsiti]	n.	黏质，黏性
2. humidity [hjuːˈmiditi]	n.	湿气，潮湿，湿度
3. flow [fləu]	n.	流程，流量，流动，(河水)泛滥，洋溢
	vi.	流动，涌流
	vt.	溢过，淹没
4. tooling [ˈtuːliŋ]	n.	用刀具加工，工具，机床安装
5. drudgery [ˈdrʌdʒəri]	n.	苦差事，苦工

6. integral [ˈintigrəl]	adj.	［数学］积分的
	n.	［数学］积分
7. differential equation		微分方程
8. relieve [riˈliːv]	vt.	减轻，解除，援救，救济，换班
9. routine [ruːˈtiːn]	n.	例行公事，常规，惯例，日常事务，程序
	adj.	常规的，平淡的，乏味的
10. optimal [ˈɔptiməl]	adj.	最佳的，最优的，最理想的
11. servomechanism [ˈsəːvəuˈmekənizəm]	n.	伺服机构(系统)，自动控制装置，跟踪器
12. relay [ˈriːlei]	n.	驿马，接替；继电器
	vt.	分程传递，使接替，转播
	vi.	转播
13. root-locus		根轨迹
14. stringent [ˈstrindʒənt]	adj.	严厉的，迫切的
15. centrifugal governor		离心调速器
16. hybrid computer		混［复]合计算机
17. unpredictable [ˈʌnpriˈdiktəbl]	adj.	不可预知的
18. prescribed		规定的
19. analogous [əˈnæləgəs]	adj.	类似的，相似的
20. common practice		常规，习惯作法，一般惯例
21. stochastic [stəuˈkæstik]	adj.	随机的，机遇的，偶然的，推测的
	n.	随机
22. optimal control		最优控制
23. deterministic [diˌtəːmiˈnistik]	adj.	可定的，明确的，决定性的，确定性的
	n.	确定性
24. adaptive and learning control		(自)适应与学习控制
25. under way		在进行中，在行进，起步的，启动的
26. terminology [ˌtəːmiˈnɔlədʒi]	n.	术语学，术语，专门名词
27. plant [plɑːnt]	n.	植物，庄稼，工厂，对象，车间，设备，联合装置
	vt.	种植，栽培，培养，安置
	vi.	种植
28. function [ˈfʌŋkʃən]	n.	官能，功能，职责，仪式；函数
	vi.	(器官等)活动，运行，行使职责
29. intricate [ˈintrikit]	adj.	复杂的，错综的，难以理解的
30. synonymous [siˈnɔniməs]	adj.	同义的
31. reference input		参考输入，基准输入
32. constant [ˈkɔnstənt]	n.	常数，恒量
	adj.	不变的，持续的，坚决的，固定的，忠心的

33. difference [ˈdifərəns] n. 差异，偏差，分歧，争论，差额，差分
adj. [数]微分的，差动的
34. i.e. [ˈaiˈiː] abbr. [拉] id est [idˈest]＝that is (to say) 也，即，就是
35. designate [ˈdezigneit] vt. 指明，指出，任命，指派
vi. 指定，指派
[ˈdezignət] adj. 指派的，任命的
36. control loop 控制回路
37. machine tools 机床
38. thermostat [ˈθəːməstæt] n. 自动调温器，温度调节装置
39. liquid level 液位
40. preset [ˈpriːˈset] vt. 事先调整，预先安置，预先调试
41. interval [ˈintəvəl] n. 间隔，距离，幕间休息
n. 时间间隔
42. set point 设定点，设定值，凝结点，调定点
43. integral [ˈintigrəl] adj. 完整的，整数的，整体的；积分的
n. 完整，部分，积分

Notes

[1] The Merriam-Webster Dictionary defines a process to be a natural, progressively continuing operation or development marked by a series of gradual changes that succeed one another in a relatively fixed way and lead toward a particular result or end; or an artificial or voluntary, progressively continuing operation that consists of a series of controlled actions or movements systematically directed toward a particular result or end.

麦里亚-韦伯斯特字典将过程定义为一种自然的、持续性的操作或演变进程，其特征是一系列渐进的变化以相对固定的方式相继发生在操作或演变进程中，并产生特定的效果或结果；或者是人为或自发的、持续性的、由一系列产生特定结果的被控操作或动作组成的工序。

句中两个 that 都引导定语从句,分别修饰 changes 和 operation；第一个 or 引导并列句。

[2] A feedback control system is one which tends to maintain a prescribed relationship between the output and the reference input by comparing these and using the difference as a means of control.

反馈控制系统的目的是通过比较来保持输出与参考输入之间的偏差为既定关系，并且利用这一偏差作为控制的手段。

句中 which 引导定语从句，修饰 one。

[3] An automatic regulating system is a feedback control system in which the reference input or the desired output is either constant or slowly varying with time and in which the primary task is to maintain the actual output at the desired value in the presence of disturbances.

自动调节系统是保持参考输入或期望的输出为常量或随时间缓慢变化的反馈系统，其主要任务是在出现扰动时，使实际输出保持为期望值。

[4] An automatic regulating system in which the output is a variable such as temperature, pressure, flow, liquid level, or pH is called a process control system.

输出为温度、压力、流量、液位或者 pH 值等变量的自动调节系统称为过程控制系统。

本句为被动语态，其中 which 引导定语从句。

[5] For example, a preset program may be such that the furnace temperature is raised to a given temperature in a given time interval and then lowered to another given temperature in some other given time interval.

例如，一个预置的程序可以是这样的, 炉温在给定时间内上升到给定值，然后在预定时间内又下降到另一给定值。

句中的 that 引导同位语从句。

Translating Skills　句子成分的转换

句子成分的转换主要指英语中的主语、谓语、宾语、表语、定语、状语、补语成分与译入语汉语的句子成分的转换。英语注重形合，在句子结构上与汉语有很大的不同。为了构造适于译入语习惯的译文，译成注重意合的汉语时就有必要进行成分转换。

1. There+be 句型中的主语译成宾语

(1) There are **eighty students** in the classroom.

教室里有**八十个学生**。(英语主语−汉语宾语)

(2) There is **a large amount of energy** wasted due to the fraction of commutator.

转换器引起的摩擦损耗了**大量的能量**。(英语主语−汉语宾语)

(3) However, for a long time there will clearly remain **a major role** for the manned aircraft.

然而在很长时间里，有人驾驶的飞行器仍将起**重要作用**。(英语主语−汉语宾语)

(4) There are **some metals** which possess the power to conduct electricity and the ability to be magnetized.

有些金属具有导电能力和磁化能力。(英语主语−汉语宾语)

(5) There is not enough **fresh air** in the hall. (英语主语−汉语宾语)

大厅里缺乏足够的**新鲜空气**。

2. 被动句里的主语译成宾语

(6) **They** will be reminded that peace is the highest aspiration of our people.

我们要提醒**他们**，和平是我国人民最高的愿望。

(7) With this information **the "phase" of the coherent train of pulses** could be traced in addition to simply determining the pulse rate.

有了这一信息，除能确定脉冲速率外，还可寻找出**这一连串脉冲的相位**。

(8) Once **the shell and membranes** are added, the organism enjoys a protected location.

一旦加上**外壳和薄膜**，里面的有机体便得到了保护。

(9) In this process, **only moderate deal load tensions** are needed.

在这个过程中，只需要**中等程度的负载张力**。

3. 含有动作意味的主语译成谓语

(10) **A view** of the Great Wall can be obtained from the plane.
从飞机上你可以**看**到长城。

(11) There is a **need** for improvement in our study.
我们的学习**需要改进**。

4. 主语译成定语

(12) **The steam engine** is only about 15% efficient.
这种蒸汽机的效率只有百分之十五左右。

(13) **The earth** is shaped like an egg.
地球的形状像鸡蛋。

5. 谓语转换成主语：表示印象、态度、特点和地位的谓语动词，翻译成汉语时可转换成宾语

(14) These pumps **are featured** by their simple operation, easy maintenance, low oil consumption and durable service.
这些水泵的**特点**是操作简便、维修容易、耗油量少、经久耐用。

(15) Your work is characterized by lack of attention to detail.
你的工作的**特点**是不注意细节。

(16) He did not **act** well in the school.
他在学校里的**表现**不好。

(17) She **figured** prominently in the whole drama.
她在整个戏剧里占了很突出的**地位**。

6. 表语转换成主语

(18) The oxygen atom is nearly 16 times as **heavy** as the hydrogen.
氧原子的**重量**几乎是氢的 16 倍。

(19) Nylon is nearly twice as **strong** as natural silk.
尼龙的**强度**约为真丝的两倍。

(20) A crystal receiver is a less complicated **structure** than a valve receiver.
晶体管收音机的**结构**不像电子管收音机那么复杂。

7. 动词 have 的宾语转换成主语时，宾语的定语通常转换成谓语，其他动词的宾语也可译成汉语的主语

(21) An automobile must have a **brake** with high efficiency.
汽车的**刹车**必须高度有效。

(22) The skyscraper has **a height** of 100 m.
这座摩天大楼的**高度**是一百米。

(23) Warmed-blood animals have a constant **body temperature.**
热血动物的**体温**是恒定的。

(24) Light beams can carry more **information** than radio signals.
光束运载的**信息**比无线电信号运载的信息多。

8. 定语转换成谓语或状语

(25) **Many** factors enter into equipment safety.
涉及设备安全性的因素**很多。**

(26) We should have a **thorough** grasp of the problem.
我们应该**彻底**理解这一问题。(转译为状语)

9. 状语转换成主语或定语

(27) **In size and appearance** the flying object is very much like our sun.
飞行物的**大小和外观**很像太阳。(当作状语的介词短语表示主语的位置、形状、性质等时，往往译成汉语的主语)

(28) **Today,** a study usually includes a consideration of the environmental impact of the project.
今天的项目研究工作通常要包括考虑该项目的环境影响在内。(转译为定语)

(29) The fabrication of digital networks has also been reported **in considerable detail.**
对数字网络的制造工艺也已作出了**相当详细的**报道。(转译为定语)

(30) The production of iron declined 25% **this year.**
今年的铁产量下降了 25%。(定语)

Exercises

1. Translate the following into Chinese.

(1) In order to develop our electronic industry, we must lay stress on the development and production of ICs.

(2) The value of the computer is that it can process a vast mass of statistical information very quickly.

(3) At unity power factor the power in a single-phase circuit is zero twice each cycle.

(4) In the decimal system the radix is 10, and each position to the left or right of the decimal point represents an increased or decreased weight as a power of 10.

(5) Use of longer wavelengths means that fewer or less complex repeaters are needed along the lightwave.

(6) In power supply, the filter is network of capacitors, resistors and inducts that eliminates the rectifier.

(7) The range may be about 1500 km at low frequencies (long wave, but much less for v.h.f.) .

2. Translate the following into English.

(1) 过程计算机的出现意味着原来采用模拟技术不能实现的算法现在可以应用了。

(2) 据报道，先进的控制可以提高产品产量，减少能量损耗，提高产品质量和过程的

安全性，减少环境排放物。

(3) 对先进控制的理解取决于个人的知识背景，可以是前馈或串级控制方案、时延补偿器、自调整或自适应的算法或优化策略的实现。

(4) 先进控制技术涉及的学科包括控制工程、信号处理、统计学、决策理论、人工智能、软件和硬件工程等。

(5) 什么装置使控制系统简化？

(6) 电流测量的基本单位是安培。

(7) 大约就在这个时候，商店和办公室都会亮起圣诞节灯光。

Reading Material　Advanced Control

Over the past 30 years, much have been written about advanced control; the underlying theory, implementation studies, statements about the benefits that its applications will bring and projections of future trends. During the 1960s, advanced control was taken to mean any algorithm or strategy that deviated from the classical three-term, Proportional-Integral-Derivative (PID) , controller. The advent of process computers meant that algorithms that could not be realized using analog technology could now be applied. Feed forward control, multivariable control and optimal control philosophies became practicable alternatives. Indeed, the modern day proliferation of so called advanced control methodologies can only be attributed to the advances made in the electronics industry, especially in the development of low cost digital computational devices (circa 1970). Nowadays, advanced control is synonymous with the implementation of computer-based technologies.

It has been recently reported that advanced control can improve product yield, reduce energy consumption, increase capacity, improve product quality and consistency, reduce product giveaway, increase responsiveness, improve process safety and reduce environmental emissions. By implementing advanced control, benefits ranging from 2% to 6% of operating costs have been quoted [Anderson, 1992]. These benefits are clearly enormous and are achieved by reducing process variability, hence allowing plants to be operated to their designed capacity.

What exactly is advanced control? Depending on an individual's background, advanced control may mean different things. It could be the implementation of feed forward or cascade control schemes, of time-delay compensators, of self-tuning or adaptive algorithms or of optimization strategies. Here, the views of academics and practicing engineers can differ significantly.

We prefer to regard advanced control as more than just the use of multi-processor computers or state-of-the-art software environments. Neither does it refer to the singular use of sophisticated control algorithms. It describes a practice which draws upon elements from many disciplines ranging from control engineering, signal processing, statistics, decision theory, artificial intelligence to hardware and software engineering. Central to this philosophy is the requirement for an engineering appreciation of the problem, an understanding of process plant behavior coupled with the judicious use of, not necessarily state-of-the art, control technologies.

This report restricts attention to control algorithms. Current approaches in this area rely heavily upon a study of system behavior and the use of process models. Therefore this report will focus only on model-based techniques. Although most of the methodologies to be described are applicable to a wide spectrum of systems, e.g. aerospace, robotics, radar tracking and vehicle guidance systems, only those pertinent to the process industries will be discussed.

New Words and Phrases

1. algorithm [ˈælgəriðəm]	n.	[数] 算法，运算法则，计算步骤，规则系统
2. proliferation [prəuˌlifəˈreiʃ ən]	n.	增殖，扩散
3. methodology [meθəˈdɔlədʒi]	n.	方法学，方法论
4. quote [kwəut]	vt.	引用，引证，提供，提出
5. discipline [ˈdisiplin]	n.	学科
6. artificial intelligence		人工智能
7. radar tracking		雷达跟踪
8. pertinent [ˈpəːtinənt]	adj.	有关的，相干的，中肯的
9. underlying [ˈʌndəˈlaiiŋ]	adj.	在下面的，根本的，基本的，潜在的[商]优先的
10. deviate [ˈdiːvieit]	vi.	背离，偏离
11. circa [ˈsəːkə]	adv.& prep.	大约
12. giveaway [ˈgivəwei]	n.	让渡，转让，泄漏，赠品，免费样品
13. cascade [kæsˈkeid]	n.	小瀑布，喷流，层叠，串联，级，级联，栅，格状物，重叠(方式)
14. state-of-the-art		艺术级的，目前发展水平的，最新的，现代的
15. judicious [dʒu(ː)ˈdiʃ əs]	adj.	明智的，有见识的，敏感的

Lesson 6 Introductions to Mathematical Models of Physical Systems

Many dynamic systems, whether they are mechanical, electrical, thermal, hydraulic, economic, biological, etc, may be characterized by differential equations. The response of a dynamic system to an input (or forcing function) may be obtained if these differential equations are solved. The equations can be obtained by utilizing physical laws governing a particular system, for example, Newton's laws for mechanical systems, Kirchhoff's laws for electrical systems, etc.

Mathematical models. The mathematical description of the dynamic characteristics of a system is called a mathematical model. The first step in the analysis of a dynamic system is to derive its model. We must always keep in mind that deriving a reasonable mathematical model is the most important part of the entire analysis.

Models may assume many different forms. Depending on the particular system and the circumstances, one mathematical representation may be better suited than other representations. For example, in optimal control problems, it is often advantageous to use a set of first-order differential equations. On the other hand, for the transient-response analysis or frequency-response analysis of single-input-single-output systems, the transfer-function representation may be more convenient than any other.

Once a mathematical model of a system is obtained, various analytical and computer tools can be used for analysis and synthesis purposes.

Simplicity versus accuracy. In obtaining a model, we must make a compromise between the simplicity of the model and the accuracy of the results of the analysis. Note that the results obtained from the analysis are valid only to the extent that the model approximates a given physical system. [1]

The rapidity with which a digital computer can perform arithmetic operations allows us to employ a new approach in formulating mathematical models. Instead of limiting models to simple ones, we may, if necessary, include hundreds of equations to describe a complete system. If extreme accuracy is not needed, however, it is preferable to obtain only a reasonably simplified model.

In deriving such a simplified model, we frequently find it necessary to ignore certain inherent physical properties of the system. In particular, if a linear lumped-parameter mathematical model (i.e., one employing ordinary differential equations) is desired, it is always necessary to ignore certain nonlinearities and distributed parameters (i.e., ones giving rise to partial differential equations) which may be present in the physical system. [2] If the effects that these ignored properties have on the response are small, good agreement will be obtained between the results of the analysis of a mathematical model and the results of the experimental study of the physical system.

In general, in solving a new problem, we find it desirable first to build a simplified model so that we can get a general feeling for the solution. A more complete mathematical model may then be built and used for a more complete analysis.

We must be well aware of the fact that a linear lumped-parameter model, which may be valid in low-frequency operations, may not be valid at sufficiently high frequencies since the neglected property of distributed parameters may become an important factor in the dynamic behavior of the system. For example, the mass of a spring may be neglected in low-frequency operations but it becomes an important property of the system at high frequencies.

Linear systems. Linear systems are ones in which the equations of the model are linear. A differential equation is linear if the coefficients are constants or functions only of the independent variable. The most important property of linear systems is that the principle of superposition is applicable. The principle of superposition states that the response produced by the simultaneous application of two different forcing functions is the sum of the two individual responses. [3] Hence, for linear systems, the response to several inputs can be calculated by treating one input at a time and adding the results. It is this principle that allows one to build up complicated solutions to the linear differential equation from simple solutions.

In an experimental investigation of a dynamic system, if cause and effect are proportional, thus implying that the principle of superposition holds, then the system can be considered linear.

Linear time-invariant systems and linear time-varying systems. Dynamic systems that are linear and are composed of time-invariant lumped-parameter components may be described by linear time-invariant differential equations. Such systems are called ***linear time-invariant***(or ***linear constant-coefficient***) systems. Systems that are represented by differential equations whose coefficients are functions of time are called linear time-varying systems. An example of a time-varying control system is a spacecraft control system. (The mass of a spacecraft changes due to fuel consumption, and the gravity force changes as the spacecraft moves away from the earth.)

Nonlinear systems. Nonlinear systems are ones which are represented by nonlinear equations. Examples of nonlinear equations are:

$$y=\sin x \tag{6-1}$$

$$y=x^2 \tag{6-2}$$

$$z=x^2+y^3 \tag{6-3}$$

(In the last equation, z is a nonlinear function of x and y.)

A differential equation is called nonlinear if it is not linear. Examples of nonlinear differential equations are:

$$\frac{\mathrm{d}^2 x}{\mathrm{d}t^2}+\left(\frac{\mathrm{d}x}{\mathrm{d}t}\right)^2+x=A\sin\omega t \tag{6-4}$$

$$\frac{d^2x}{dt^2}+\left(x^2-1\right)\frac{dx}{dt}+x=0 \tag{6-5}$$

$$\frac{d^2x}{dt^2}+\frac{dx}{dt}+x+x^2=0 \tag{6-6}$$

Although many physical relationships are often represented by linear equations, in most cases actual relationships are not quite linear. In fact, a careful study of physical systems reveals that even so-called “linear systems” are really linear only in limited operating ranges. In practice, many electromechanical systems, hydraulic systems, pneumatic systems, etc., involve nonlinear relationships among the variables. For example, the output of a component may saturate for large input signals. There may be a dead space that affects small signals. (The dead space of a component is a small range of input variations to which the component is insensitive.) Square-law nonlinearity may occur in some components. For instance, dampers used in physical systems may be linear for low-velocity operations but may become nonlinear at high velocities, and the damping force may become proportional to the square of the operating velocity.

Note that some important control systems are nonlinear for signals of any size. For example, in on-off control systems, the control action is either on or off, and there is no linear relationship between the input and output of the controller.

The most important characteristic of nonlinear systems is that the principle of superposition is not applicable. Procedures for finding the solutions of problems involving such nonlinear systems, in general, are extremely complicated. Because of this mathematical difficulty attached to nonlinear systems, one often finds it necessary to introduce “equivalent” linear systems in place of nonlinear ones. [4] Once a nonlinear system is approximated by a linear mathematical model, a number of linear tools may be applied for analysis and design purpose, and there are various linearization techniques in practical application.

New Words and Phrases

1. dynamic [daiˈnæmik]	adj.	动态的，动力学的，动力的，有活力的，有生命力的
2. thermal [ˈθəːm(ə)l]	adj.	热的，热量的，热力的，温度的]
	n.	上升热气流
3. hydraulic [haiˈdrɔːlik]	adj.	水力的，水压的，液压的
4. forcing function		作用函数
5. utilize [juːˈtilaiz]	vt.	利用
6. law [lɔː]	n.	法律，诉讼，法学，法治，司法界，规律，定律
	vt.	对……起诉，控告
	abbr.	[军] Light Anti-Tank Weapon 轻型反坦克武器
7. assume [əˈsjuːm]	vt.	假定，设想，采取，采用，呈现，承担
8. optimal [ˈɔptiməl]	adj.	最佳的，最理想的，最优的
9. first-order		一阶的

10. transient [ˈtrænziənt]	adj.	短暂的，瞬时的，暂时的
	n.	瞬时现象
11. transient-response		暂态响应
12. analytical [ˌænəˈlitikəl]	adj.	分析的，解析的，分析法的〈语法〉善于分析的
13. synthesis [ˈsinθisis]	n.	综合，合成
14. versus [ˈvəːsəs]	prep.	对……(指诉讼，比赛等中)，反对，与……相对
15. compromise [ˈkɔmprəmaiz]	n.	妥协，折衷，和解，让步
	vt., vi.	妥协，让步，折衷，危害
16. rapidity [rəˈpiditi]	n.	速度，迅速，急速，快
17. formulate [ˈfɔːmjuleit]	vt.	用公式表示，明确地表达，简述，规划，设计
	vi.	阐明
18. employ [imˈplɔi]	vt.	雇用，用，使用
	n.	雇用
19. approach [əˈprəutʃ]	n.	接近，逼近，走进，方法，步骤，途径，通路
	vt.	接近，动手处理
	vi.	靠近
20. property [ˈprɔpəti]	n.	财产，所有物，所有权，性质，特性，(小)道具
21. lump [lʌmp]	n.	块(尤指小块)，肿块，笨人
	vt.	使成块状，混在一起，忍耐，笨重地移动
22. lumped-parameter		集中参数
23. give rise to		引起，导致，使发生
24. ordinary differential equations		常微分方程
25. partial differential equation		偏微分方程
26. spring [spriŋ]	n.	春天，跃起，泉，弹簧，发条，弹性，弹力，根源
	v.	跳，跃，跃出，使跳跃，使爆炸，触发
27. coefficient [kəuiˈfiʃənt]	n.	[数]系数，因数，常数，率，折算率，共同作用，协同因素
28. independent variable		自变量，独立变量
29. mass [mæs]	n.	块，质量，群众，大多数，大量
	adj.	群众的，大规模的
	vt.	使集合
	vi.	聚集
30. superposition [ˌsjuːpəpəˈziʃən]	n	重叠，重合，叠合，叠加
31. the principle of superposition		叠加原理
32. linear time-invariant (constant-coefficient) system		线性时不变(定常)系统

33. electromechanical [iˌlektrəumiˋkænikəl]	adj.	[机]电动机械的，机电的，电机的
34. pneumatic [nju(:)ˈmætik]	adj.	装满空气的，可充空气的，有气胎的，汽力的，气动的，风力的，灵魂的
	n.	气胎
35. dead space		死舱位，静区，死区，无信号区，阴影区
36. square-law		平方律
37. nonlinearity [ˌnɔnliniˈæriti]	n.	非(直)线性(特性)
38. damper [ˈdæmpə]	n.	抑制的因素，节气阀，阻尼器，断音装置，风门，令人扫兴的人(物)
39. damp [dæmp]	n.	湿气
	adj.	潮湿的
	vt.	使潮湿，阻尼，使衰减，使沮丧，控制，抑止，使减少，使降低
40. simplify [ˈsimplifai]	vt.	单一化，简单化，使简易，使易做，简化
41. equivalent [iˈkwivələnt]	adj.	相等的，相当的，同意义的
	n.	等价物，相等物
42. invariant [inˈvɛəriənt]	adj.	无变化的，不变的
	n.	[数]不变式，不变量
43. represent [ˌri:priˈzent]	vt.	表现，声称，象征，扮演，回忆，再赠送，再上演
	vi.	提出异议
44. linearization [ˌliniəraiˋzeiʃən;-riˋz-]	n.	线性化

Notes

[1] Note that the results obtained from the analysis are valid only to the extent that the model approximates a given physical system.

应当注意的是，分析结果的准确程度仅取决于数学模型对给定物理系统的近似程度。

句中 Note 后 that 引导的是宾语从句，过去分词短语 obtained from the analysis 作定语，修饰 the results。定语从句 that the model approximates a given physical system 修饰 the extent。

[2] In particular, if a linear lumped-parameter mathematical model (i.e., one employing ordinary differential equations) is desired, it is always necessary to ignore certain nonlinearities and distributed parameters (i.e., ones giving rise to partial differential equations) which may be present in the physical system.

特别是在需要采用线性集总参数数学模型(即常微分方程)时，总是要忽略掉物理系统中存在的一定的非线性因素和分布参数(即产生偏微分方程的参数)。

句中的 it 作形式主语，代替不定式短语 to ignore…作主语。which 引导的定语从句修饰 certain nonlinearities and distributed parameters。

[3] The principle of superposition states that the response produced by the simultaneous application of two different forcing functions is the sum of the two individual responses.

叠加原理说明，两个不同的作用函数同时作用于系统时的响应等于两个作用函数单独作用时的响应之和。

句中的过去分词短语 produced by…作定语，修饰宾语从句中的主语 the response。

[4] Because of this mathematical difficulty attached to nonlinear systems, one often finds it necessary to introduce “equivalent” linear systems in place of nonlinear ones.

由于非线性系统在数学上(求解)的困难，常需引入“等效”的线性系统来代替非线性系统。

句中的过去分词短语 attached to…作定语，修饰 difficulty。

Translating Skills　长句的译法

所谓长句，主要指语法结构复杂，修饰成分颇多，内容层次在两个以上的复合句，亦可指带有修饰性短语或附加成分的简单句或并列句。修饰性短语包括介词短语、不定式短语、分词短语、动名词短语和形容词短语；附加成分主要指插入语、同位语和独立成分。在科技英语中，大量使用长句可以严密、准确、客观地表达多重密切相关的概念。但由于英汉两种语言连接句子的手段不同，表述概念、叙述事情和论述事理的逻辑有别，在英汉互译的过程中要注重了解两者的差异，认真进行语法分析，吃透句子所要表达的深层意义，根据英汉表达的习惯，翻译出符合译入语习惯的句子。

英语长句的特点

在英语长句中，简单句含义丰富，有一个主干，即有主语、谓语、宾语(表语)，同时又有多个修饰成分用不同的手段与主干相连，诸如有单个形容词、形容词短语、介词短语、分词短语和不定式作定语；复合句包括并列复合句、主从复合句或并列主从复合句：有层层包孕关系的定语从句修饰先行词，有原因、结果、让步、方式、条件、目的和时间状语从句，表示主从句之间的逻辑关系，有副词、副词短语等所作的状语。但并非每个句子都包含所有类型。

(1) In a typical modern Hi-Fi system, the signals will come from a unit like a CD player, FM tuner, or a Tape/Minidisk unit.

分析：该句是简单句，其主要成分是 the signals(主语)+will come from(谓语)+a unit(宾语)。带有两个介词短语：In a typical modern hi-fi system 作状语，修饰整个句子，表示范围；like a CD player, FM tuner, or a Tape/Minidisk unit 短语作宾语的后置定语，指具体设备。

翻译：在典型的现代高保真系统中，信号是来自于 CD 播放器、调频收音机或磁带/小型磁盘机等设备。

(2) The advent of jet and rocket propulsion, and of nuclear reactors, has shown that the materials which previously served for constructional purposes are no longer wholly satisfactory for the manufacture of equipment on which the efficient functioning of these new sources of power depends.

分析：该句是主从复合句，由一个主句和 4 个从句组成。其中 The advent(主语) … + has shown (谓语) + that clause (宾语) 为主句的框架；of jet and rocket propulsion, and of nuclear reactors 作主语的后置定语；that 从句作句子的宾语；宾语从句里又套有两个由 which 引导的从句，直接跟在各自的先行词 the materials 和介词短语中的 equipment 之后，构成层层推进的关系。

翻译：喷气式发机、火箭助推器以及核反应堆的出现表明过去的建材再也不能令人满意地用来建造那些有效使用新能源的设备。

汉语长句的特点 汉语长句多以意合的方式组合在一起，缺少像英语中的关系代词或关系副词等标志逻辑关系的连接词。句子多以时间发生的先后顺序或动作之间的先后关系排列。

长句的几种译法(这里主要讲英语译成汉语)

1. *顺译法*

当英语原句所表达的思想与意义在句型结构(如主谓结构、主谓宾结构、主系和部分主谓状、主谓宾状结构)、时间顺序、句内逻辑顺序(像因果关系、对比转折关系、动宾关系和条件假设关系)上基本与汉语句子的语序一致时；或句子同主多谓、同谓多宾时常采用顺译法，即大体按照英语句子的实际先后顺序进行翻译。但不能拘泥于词词对照，经常会有局部语序的变化。如：

(3) The power amplifier has no way to “know in advance” what kind of loudspeaker you will use, so simply adopts the convention of asserting a voltage level to indicate the required signal level at each frequency in the signal and supplying whatever current the loudspeaker then requires.(句内逻辑顺序为因果关系，由 so 前后连接；且谓语 has 和 adopts 具有共同的主语)

功率放大器不可能预先知道将会使用的扬声器类型，因此就简单地按常规情况处理，提供一定大小的电压，表示信号中任意频率下所需信号的幅度，并提供扬声器所需要的电流。

(4) Plastics is made from water which is a natural resource inexhaustible(取之不竭的，无穷尽的)and available everywhere, coal which can be mined through automatic and mechanical processes at less cost and lime which can be obtained from the calcinations (煅烧) of limestone(石灰石)widely present in nature.(同谓多宾，即 is made from 后有 3 个并列宾语 water，coal，lime，分别用逗号和 and 连接起来)

塑料是由水、煤和石灰石制成的——水是取之不尽的、到处可以获得的天然资源；煤是用自动化和机械化的方法开采的，成本较低；石灰是由煅烧自然界中广泛存在的石灰石得来的。

2. *逆译法*

主要指英汉对译的句子的时间顺序、句内逻辑顺序恰恰相反。如：

(5) It is very interesting to note the differently chosen operating mechanism by the different manufacturers, in spite of the fact that the operating mechanism has a major influence on the reliability of the circuit-breakers.

尽管操作机构对断路器的可靠性具有主要影响，但注意不同的制造厂按不同形式选择操作机构是非常有趣的。

(6) This will remain true whether we are dealing with the application of psychology to advertising and political propaganda, or engineering to the mass media of communication，or of medical science to the problem of over-population or old age.(转引自林相周《英语理解与翻译》。上海外语教育出版社，1998)

无论我们说的是把心理学应用于广告宣传和政治宣传，还是把工程学应用于大众传播媒体，或是把医学运用于人口过剩问题和老年问题，这种情况总是如此。

3. 拆分法

当英语长句中的主句与从句、或介词短语及分词短语、副词等所修饰的词与词之间的关系不是很密切时，可根据汉语一个小句表达一层意思的习惯，对原文的各个意思层进行分解，把英汉长句拆开成分句来译。如：

(7) The diode consists of a tungsten filament, which gives off electrons when it is heated, and a plate toward which the electrons migrate when the field is in the right direction.

二极管由一根钨丝和一个极板组成，钨丝受热时就放出电子；当电场方向为正时，这些电子就移向极板。

(8) The system can conceivably eventually replace the yellow pages, newspaper and magazine advertising and personal contact from sales personnel.

可预见，这一系统最终能取代电话黄页、报刊广告和销售人员的个人联系。

4. 整合法

主要指当英汉长句不能按照上述 3 种方法进行翻译时，就要根据译入语的习惯，适当调整句子的顺序，准确反映句子的深层含义。如：

(9) My assistant who had carefully read through the instructions before doing his experiment, could not obtain satisfactory results because he followed them mechanically.

虽然我的助手在做实验前仔细阅读过指导书，但是因为他机械地照搬，没能取得满意的结果。

(10) There is a great deal of difference in the ability of different substances to conduct or insulate and that decides which material is the best to use for a particular purpose.

不同物质的传导和绝缘的能力有很大差别，这就决定了那种材料最适用于某一特定的用途。

Exercises

1. Translate the following into Chinese.

(1) In control theory, functions called “transfer functions” are very often used to characterize the input-output relationships of linear time-invariant systems.

(2) The transfer function is an expression relating the output and input of a linear time-invariant system in terms of the system parameters and is a property of the system itself, independent of the input or driving function.

(3) The transfer function of a linear time-varying system is defined to be the ratio of the

Laplace transform of the output (response function) to of the Laplace transform of the input (driving function) , under the assumption that the initial conditions are zero.

(4) An amplifier circuit equipped with some amount of negative feedback is not only more stable, but it tends to distort the input waveform to a lesser degree and is generally capable of amplifying a wider range of frequencies.

(5) It is generally held that the most efficient method of railway operation, and ultimately the most economical, given a reasonably cheap electricity supply, is with electricity as the motive power.

(6) Since the intensity of the electron beam is determined by the video signal that has been picked up by the antenna and amplified by the receiver electronics, it reproduces on the picture tube the scene being televised by whatever channel you have selected.

(7) Despite the existence of numerous capabilities for recording PQ waveforms, there is a great shortage of qualified power systems engineers who can analyze the data and diagnose/solve the problems.

2. Translate the following into English.

(1) 与数学描述的抽象概括不同，方块图(block diagram)具有能够表示出实际系统中信号实际流向的特点。

(2) 数学模型是对一个实际物理系统动态特性的数学描述，微分方程和传递函数是最常用的形式。

(3) 许多实际系统由于其变量之间存在饱和等非线性关系，就只能用非线性微分方程描述。

(4) 在建立系统的数学模型时，通常要忽略一些次要的因素，这样可以得到简化的模型，以便于进行分析和设计。

(5) 我有一个问题弄不懂，想请教你，你能回答吗?

(6) 任何占据空间、具有重量的东西都是物质。

(7) 我们把火力发电厂建在需要电能的地方。

Reading Material　Electrical Engineering

As early as the latter part of the 16th century, experimenters were exploring the behavior of static electricity. W. Gilbert experimented with electric charges and discharges. In 1750 Benjamin Franklin proved that lightning was electrical in nature. Neither investigator discovered anything that was significant from the standpoint of the applications of electricity. Discovery of the presence of magnetism in certain rocks preceded the earliest knowledge of electricity. Such knowledge was common about 600 B. C.. Applications of electrical knowledge were completely absent in this era.

In 1800 A. Volta discovered the principle of the electric battery. The voltaic cell was one of the most important discoveries in the history of the electrical art, because it provided a continuous source of appreciable amounts of electric power at reasonably low voltage. It was an essential component of the early communication systems, such as the telephone and telegraph.

The first United States' patent on the electrical telegraph was obtained by J. Groat in 1800. The invention of a practical electromagnet was announced by Joseph Henry in 1827. These inventions by Groat and Henry opened the way for a still more significant invention, the electromagnetic telegraph. The principle of this forerunner of the communications industry was conceived in 1831, proven practical in 1837, and patented 1840 by Samuel. F. B. Morse.

Few developments have had greater impact on American life than Morse's invention. His idea paved the way for the first system of electrical communication, the telegraph. This in turn led to the telephone and later to the wireless telegraph.

The discovery of electromagnetic induction by Michael Faraday in 1831 established many principles for modern machines. Motors, generators, transformers, and many other electrical devices found in heavy electrical industry were made possible by the discoveries of Faraday. The contributions of Faraday in the electrical power industry are comparable to those of Morse in the field of communications.

One of the first important developments based on the disclosures of Faraday was the electric dynamo. English patent no.1858 describes the principle of operation. In the following years many types dc generators were developed and used commercially. The Gramme-ring armature was one of the first used in conjunction with a commutator. This machine was somewhat inefficient, but it provided a source of relatively high voltage at a reasonably large power capacity (up to 100 kW)

With the development of the high-resistance carbon filament lamp by Thomas Edison in 1880, the dc generator became one of the essential components of the constant-potential lighting system. Commercial lighting and residential lighting became practical and the electric light and power industry was born. One of the most common uses for direct current during this period was for street lighting.

The first transformer was announced in 1883. This device probably did more to revolutionize the systems of power transmission than any other. The advantages of high-voltage low-current systems over the low-voltage high-current systems of power transmission were well known. Following the discovery of the transformer, power could be generated at low voltages, transformed to higher voltages for transmission over great distances (several hundred miles) , and then reduced by transformers to lower values for utilization.

Since 1945 great advances have been made as the result of the invention of the transistor. This solid-state device has made possible the miniaturization of many components, integrated circuits, and calculators. During this same period, research in electron optics has preceded the development of lasers and holography.

The rate of growth of research in electrical engineering was enhanced in the 1940s as a result of support of Federal agencies. Many ideas associated with the military effort of that period are now being used commercially and for research purposes. Microwaves have become part of modern communication systems. The development of semiconductors has made possible more rugged, smaller, and cheaper systems. Research in miniaturization has greatly increased the speed of modern computers. The laser has provided communication systems operative over millions of miles. Integrated circuits have reduced size and weights and made practical interplanetary and satellite communications. Planetary radar astronomy and radio astronomy are also the result of adaptations to engineering systems of electrical components developed through research.

New Words and Phrases

1. era [ˈiərə]	n.	时代，年代，纪元，时期，[地]代
2. voltaic [vɔlˈteiik]	adj.	[电工]电流的，电压的，伏打的
3. voltaic cell		[电]伏打电池，原电池，伽伐尼电池，一次电池
4. art [ɑːt]	n.	艺术，艺术品，美术，技术，技巧，巧妙，权术，手段，人工，技工，工匠
	adj.	人工的，人造的，艺术的，技术的
5. pave the way for		为……铺平道路，为……做好准备
6. generator [ˈdʒenəreitə]	n.	发电机，发生器
7. transformer [trænsˈfɔːmə(r), trɑː-]	n.	变压器
8. dynamo [ˈdainəməu]	n.	发电机(尤指直流发电机)，电动机
9. in conjunction with		与……协力
10. commutator [ˈkɔmjuteitə]	n.	换向器，转接器
11. inefficient [ˌiniˈfiʃənt]	adj.	效率低的，效率差的，(指人)不能胜任的，无能的
12. Gramme-ring armature		格莱姆环形电枢
13. potential [pəˈtenʃ(ə)l]	adj.	潜在的，可能的，势的，位的
	n.	潜力，电压，电势，电位
14. filament [ˈfiləmənt]	n.	细丝，灯丝
15. solid-state		固态的，使用电晶体的，不用真空管的
16. miniaturization [miniətʃəˌraiˈzeiʃən]	n.	小型化
17. holography [həˈlɔgrəfi]	n.	全息摄影术，全息术
18. microwave [ˈmaikrəuweiv]	n.	微波(波长为 1 毫米至 30 厘米的高频电磁波)
19. rugged [ˈrʌgid]	adj.	高低不平的，崎岖的，粗糙的，有皱纹的
20. operative [ˈɔpərətiv; (*US*) ˈɑpəreitiv]	adj.	起作用的，生效的，手术的
	n.	工人，技工
21. interplanetary [ˌintə(ː)ˈplænitəri]	adj.	行星间的，太阳系内的
22. Faraday [ˈfærədi, -dei]	n.	[电]法拉第(电量单位，约等于 96500 库仑)，法拉第，迈克尔：(1791—1867)英国物理学、化学家，发现电磁感应(1831 年)并提出相应理论，后被麦克斯韦和爱因斯坦进一步发展
23. radio astronomy		射电天文学

Lesson 7 Basic Control Actions and Industrial Automatic Controls

An automatic controller compares the actual value of the plant output with the desired value, determines the deviation, and produces a control signal which will reduce the deviation to zero or to a small value. [1] The manner in which the automatic controller produces the control signal is called the control action.

Here we shall present the basic control actions commonly used in industrial automatic controllers. First we shall introduce the principle of operation of automatic controllers and the methods for generating various control signals, such as the use of the derivative and integral of the error signal. Next we shall discuss the effects of particular control modes on the system performance. Then we shall give a brief discussion of methods for reducing the effects of external disturbances on the system performance. Finally, we shall introduce fluid amplifiers, present basic principles of fluidics, and discuss applications of fluidic devices.

Classifications of industrial automatic controllers. Industrial automatic controllers may be classified according to their control action as:

(1) two-position or on-off controllers;

(2) proportional controllers;

(3) integral controllers;

(4) proportional-plus-integral controllers;

(5) proportional-plus-derivative controllers;

(6) proportional-plus-derivative-plus-integral controllers.

Most industrial automatic controllers use electricity or pressurized fluid such as oil or air as power sources. Automatic controllers may also be classified according to the kind of power employed in the operation, such as pneumatic controllers, hydraulic controllers, or electronic controllers. What kind of controller to use must be decided by the nature of the plant and the operating conditions, including such considerations as safety, availability, reliability, accuracy, weight, and size.

Elements of industrial automatic controllers. An automatic controller must detect the actuating error signal, which is usually at a very low power level, and amplify it to a sufficiently high level. [2] Thus, an amplifier is necessary. The output of an automatic controller is fed to a power device, such as a pneumatic motor or valve, a hydraulic motor, or an electric motor.

The controller usually consists of an error detector and amplifier. The measuring element is a device that converts the output variable into another suitable variable, such as a displacement, pressure, or electric signal, which can be used for comparing the output to the reference input signal. This element is in the feedback path of the closed-loop system. The set point of the controller must be converted to a reference input of the same units as the feedback signal from the measuring element. The amplifier amplifies the power of the actuating error signal, which in turn operates the actuator. The actuator is an element which alters the input to the plant according to the control signal so that the feedback signal may be brought into correspondence with the reference input signal.

Self-operated controllers. In most industrial automatic controllers, separate units are used for the measuring element and for the actuator. In a very simple one, however, such as a self-operated controller, these elements are assembled in one unit. Self-operated controllers utilize power developed by the measuring element and are very simple and inexpensive. The set point is determined by the adjustment of the spring force. The controlled pressure is measured by the diaphragm. The actuating error signal is the net force acting on the diaphragm. Its position determines the valve opening.

The operation of self-operated controller is as follows: Suppose that the output pressure is lower than the reference pressure, as determined by the set point. Then the downward spring force is greater than the upward pressure force, resulting in a downward movement of the diaphragm. This increases the flow rate and raises the output pressure. When the upward pressure force equals the downward spring force, the valve plug stays stationary and the flow rate is constant. Conversely, if the output pressure is higher than the reference pressure, the valve opening becomes small and reduces the flow rate through the valve opening. Such a self-operated controller is widely used for water and gas pressure control. In such a controller, the flow rate through the valve opening is approximately proportional to the actuating error signal.

Control actions. The following six basic control actions are very common among industrial automatic controllers: two-position or on-off, proportional, integral, proportional-plus-integral, proportional-plus-derivative, and proportional-plus-derivative-plus-integral control action. Note that an understanding of the basic characteristics of the various actions is necessary in order for the control engineer to select the one best suited to his particular application. [3]

Two-position or on-off control action. In a two-position control system, the actuating element has only two fixed positions which are, in many cases, simply on and off. Two-position or on-off control is relatively simple and inexpensive and, for this reason, is very widely used in both industrial and domestic control systems.

Let the output signal from the controller be $m(t)$ and the actuating error signal be $e(t)$. In two-position control, the signal $m(t)$ remains at either a maximum or minimum value, depending on whether the actuating error signal is positive or negative, so that

$$\begin{aligned} m(t) &= M_1 \text{ for } e(t) > 0 \\ &= M_2 \text{ for } e(t) < 0 \end{aligned}$$

where M_1 and M_2 are constants. The minimum value M_2 is usually either zero or $-M_1$. Two-position controllers are generally electrical devices, and an electric solenoid-operated valve is widely used in such controllers. Pneumatic proportional controllers with very high gains act as two-position controllers and are sometimes called pneumatic two-position controllers.

Considering a liquid-level control system with two-position control, the valve is either open or closed. Thus the water inflow rate is either a positive constant or zero. The output signal continuously moves between the two limits required to cause the actuating element to move from one fixed position to the other. [4] Notice that the output curve follows one of two exponential curves, one corresponding to the filling curve and the other to the emptying curve. Such output oscillation between two limits is a typical response characteristic of a system under two-position control.

We may notice that the amplitude of the output oscillation can be reduced by decreasing the differential gap. This, however, increases the number of on-off switchings per minute and reduces the useful life of the component. The magnitude of the differential gap must be determined by such considerations as the accuracy required and the life of the component. [5]

Proportional control action. For a controller with proportional control action, the relationship between the output of the controller $m(t)$ and the actuating error signal $e(t)$ is

$$m(t) = k_p e(t) \tag{7-1}$$

or, in Laplace-transformed quantities,

$$\frac{M(s)}{E(s)} = k_p \tag{7-2}$$

where k_p is termed the proportional sensitivity or the gain.

Whatever the actual mechanism may be and whatever the form of the operating power, the proportional controller is essentially an amplifier with an adjustable gain.

Integral control action. In a controller with integral control action, the value of the controller output $m(t)$ is changed at a rate proportional to the actuating error signal $e(t)$. Namely,

$$\frac{\mathrm{d}m(t)}{\mathrm{d}t} = k_t e(t) \tag{7-3}$$

or

$$m(t) = k_t \int_0^t e(t)\mathrm{d}t \tag{7-4}$$

where k_t is an adjustable constant. The transfer function of the integral controller is

$$\frac{M(s)}{E(s)} = \frac{k_t}{s} \tag{7-5}$$

If the value of $e(t)$ is doubled, then the value of $m(t)$ varies twice as fast. For zero actuating error, the value of $m(t)$ remains stationary. The integral control action is sometimes called reset control.

Proportional-plus-integral control action. The control action of a proportional-plus-integral controller is defined by the following equation:

$$m(t) = k_p e(t) + \frac{k_p}{T_t}\int_0^t e(t)\mathrm{d}t \tag{7-6}$$

or the transfer function of the controller is

$$\frac{M(s)}{E(s)} = k_p(1+\frac{1}{T_t s}) \tag{7-7}$$

where k_p represents the proportional sensitivity or gain, and T_t represents the integral time. Both k_p and T_t are adjustable. The integral time adjusts the integral control action, while a change in the value of k_p affects both the proportional and integral parts of the control action. The inverse of the integral time T_t is called the reset rate. The reset rate is the number of times per minute that the proportional part of the control action is duplicated. Reset rate is measured in terms of repeats per minute.

Proportional-plus-derivative control action. The control action of a proportional-plus-derivative controller is defined by the following equation:

$$m(t) = k_p e(t) + k_p T_d \frac{\mathrm{d}e(t)}{\mathrm{d}t} \tag{7-8}$$

where k_p represents the proportional sensitivity and T_d represents the derivative time. Both k_p and T_d are adjustable. The derivative control action, sometimes called rate control, is where the magnitude of the controller output is proportional to the rate of change of the actuating error signal. [6] The derivative time T_d is the time interval by which the rate action advances the effect of the proportional control action. The derivative control action has an anticipatory character. As a matter of course, however, derivative control action can never anticipate any action that has not yet taken place.

While derivative control action has an advantage of being anticipatory, it has the disadvantages that it amplifies noise signals and may cause a saturation effect in the actuator.

Note that derivative control action can never be used alone because this control action is effective only during transient periods.

Proportional-plus-derivative-plus-integral control action. The combination of proportional control action, derivative control action, and integral control action is termed proportional-plus-derivative-plus-integral control action. This combined action has the advantages of each of the three individual control actions. The equation of a controller with this combined action is given by

$$m(t) = k_p e(t) + k_p T_d \frac{\mathrm{d}e(t)}{\mathrm{d}t} + \frac{k_p}{T_t}\int_0^t e(t)\mathrm{d}t \tag{7-9}$$

or the transfer function is

$$\frac{M(s)}{E(s)} = k_p(1+T_d s+\frac{1}{T_t s}) \tag{7-10}$$

where k_p represents the proportional sensitivity, T_d represents the derivative time, and T_t represents the integral time.

Effects of the measuring element on system performance. Since the dynamic and static characteristics of the measuring element affect the indication of the actual value of the output variable, the measuring element plays an important role in determining the overall performance of the control system. [7] The measuring element usually determines the transfer function in the feedback path. If the time constants of a measuring element are negligibly small compared with other time constants of the control system, the transfer function of the measuring element simply becomes a constant. The response of a thermal measuring element is often of the overdamped second-order type.

Block diagrams of automatic control systems. A block diagram of a simple automatic control system may be obtained by connecting the plant to the automatic controller, as shown in Fig. 7.1. [8] Feedback of the output signal is accomplished by the measuring element. The equation relating the output variable $C(s)$ to the reference input $R(s)$ and disturbance variable $N(s)$ may be obtained as follows:

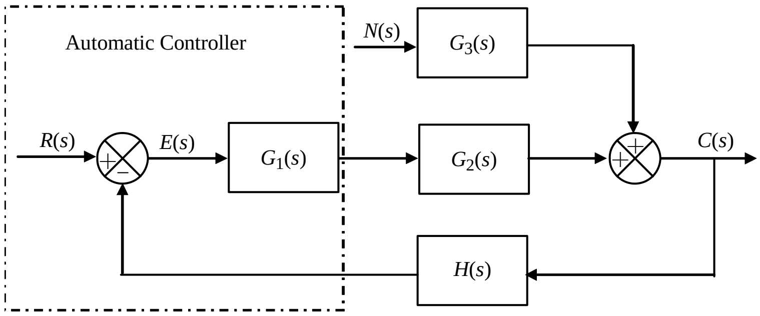


Fig.7.1　Block diagram of a control system

$$C(s)=\frac{G_1(s)G_2(s)}{1+G_1(s)G_2(s)H(s)}R(s)+\frac{G_3(s)}{1+G_1(s)G_2(s)H(s)}N(s) \qquad (7\text{-}11)$$

In process control systems, we are usually interested in the response to the load disturbance $N(s)$. In servomechanisms, however, the response to a varying input $R(s)$ is of most interest.

Later we shall illustrate the fact that proportional controllers utilize the principle of negative feedback in themselves. We shall give a detailed discussion of the principle by which proportional controllers operate by considering pneumatic ones. We shall then show that the same principle applies to hydraulic and electronic controllers. Throughout this discussion, we shall place emphasis on the fundamental principles rather than on the details of the operation of the actual mechanisms.

New Words and Phrases

1. deviation [ˌdiːviˈeiʃən]	n.	明显异化，偏差，偏离，背离，越轨
2. control action		控制作用
3. error signal		误差(偏差)信号
4. fluid [ˈflu(ː)id]	n.	流动性，流度，流体
	adj.	流动的，流畅的，流体的，不固定的，可改变的
5. fluidics [fluˈidiks]	n.	应用流体学
6. two-position or on-off controller		双位或继电器型控制器

7. proportional-plus-derivative-plus-integral controller		比例微分积分控制器(即 PID 控制器)
8. actuate [ˈæktjueit]	vt.	开动(机器等)，驱使，促使，激励(某人做某事)
9. displacement [disˈpleismənt]	n.	移置，转移，取代，置换，位移，排水量
10. correspondence [ˌkɔrisˈpɔndəns]	n.	相应，通信，信件，符合，一致，和谐，相似
	adj.	通信的，函授的
11. bring into correspondence with	vt.	使与……一致，使与……联络
12. actuator [ˈæktjueitə]	n.	激励者，制动器，执行机构，传动装置
13. diaphragm [ˈdaiəfræm]	n.	横隔膜，膜片，控光装置，镜头上的光圈，(电话等)振动膜
14. net [net]	n.	网，网络，网状物，净利，实价
	adj.	净余的，纯粹的
	vt.	用网捕，净赚，得到
	vi.	编网
15. flow rate		流速
16. two-position or on-off control action		双位或继电器型控制
17. domestic [dəˈmestik]	adj.	家庭的，国产的，国内的，驯服的
	n.	佣人，[pl.] [美]国货
18. solenoid [ˈsəulinɔid]	n.	[电] 螺线管，筒形线圈，电磁铁，网络，网络管
19. inflow [ˈinfləu]	n.	流入，流入物
20. exponential [ˌekspəuˈnenʃəl]	n.	指数，倡导者，演奏者，例子
	adj.	指数的，幂数的
21. the filling curve		灌水曲线
22. the emptying curve		放水曲线
23. oscillation [ˌɔsiˈleiʃən]	n.	摆动，振动，振荡，振幅，消长度，上下波动，[无]发杂音
24. amplitude [ˈæmplitjuːd]	n.	广阔，丰富，振幅
25. curve [kəːv]	n.	曲线，弯曲，[棒球]曲线球，[统]曲线图表
	vt.	弯，使弯曲
	vi.	成曲形
26. differential gap		差动间隙

27. Laplace [lɑːˈplɑːs]		拉普拉斯(Pierre Simon,Marquis de，1749—1827)法国天文学家、数学家
28. Laplace transform		拉普拉斯变换，拉氏变换
29. term [təːm]	n.	学期，期限，期间，条款，条件，术语，〈数〉项
	vt.	称为，把……叫作
30. proportional [prəˈpɔːʃənl]	adj.	比例的，成比例的，相称的，均衡的
31. proportional sensitivity or the gain		比例灵敏度或增益
32. stationary [ˈsteiʃ(ə)nəri]		固定的，静止的，不变的
33. inverse [ˈinˈvəːs]	adj.	倒转的，反转的，颠倒的，相反的，倒数的
	n.	反面，倒数
	vi.	倒转
34. duplicate [ˈdjuːplikeit]	adj.	复制的，副的，两重的，两倍的，完全相同的
	n.	复制品，副本
	vt.	复写，复制，使加倍，使成双
35. rate control		速率控制
36. advance [ədˈvɑːns]	n.	前进，提高，发展，预付款
	v.	前进，提前，提出，预付
	adj.	前面的，预先的，事先的，前进的
37. anticipatory [ænˈtisipeitəri]	adj.	预料的，预想的，预期的，预先做的，预先发生的
38. anticipate [ænˈtisipeit]	v.	预期，期望，过早使用，先人一着，占先，预订，预见
39. transient period		过渡周期，暂态过程，平息[稳定]时间
40. feedback path		反馈通道，反馈回路
41. negligible [ˈneglidʒəbl]	adj.	可以忽略的，不予重视的 negligibly adv.
42. second-order		二阶的
43. block diagram		方块图
44. load disturbance		负荷(载)扰动
45. negative feedback		负反馈
46. overdamp [əuvəˈdæmp]		过阻尼，阻尼超过，强衰减
47. underdamp [ˈʌndəˈdæmp]		不完全衰减[减震]，欠阻尼
48. servomechanism [ˈsəːvəuˈmekənizəm]	n.	伺服机构(系统)，随动系统，跟踪系统，自动控制装置，自动驾驶装置

Notes

[1] An automatic controller compares the actual value of the plant output with the desired value, determines the deviation, and produces a control signal which will reduce the deviation to zero or to a small value.

控制器把对象的实际输出与期望值进行比较，确定偏差，并产生一个使误差为零或微小值的控制信号。

句中的 compares，determines 和 produces 并列作为 controller 的谓语，which 引导的定语从句修饰 signal。

[2] An automatic controller must detect the actuating error signal, which is usually at a very low power level, and amplify it to a sufficiently high level.

自动控制器必须检测出功率通常很小的误差信号，并将其放大到足够的强度。

句中 which 引导的非限制性定语从句修饰 the actuating error signal。

[3] Note that an understanding of the basic characteristics of the various actions is necessary in order for the control engineer to select the one best suited to his particular application.

应当说明的是，为了方便控制工程师选择一种最适于特定用途的控制作用，因而了解各种控制作用的基本特性是十分必要的。

这是一个祈使句。句中 that 引导的宾语从句作 note 的宾语。过去分词短语 suited to 作定语，修饰 the one。

[4] The output signal continuously moves between the two limits required to cause the actuating element to move from one fixed position to the other.

输出信号在两个要求的极限位置之间连续变化，使执行元件从一个固定位置运动到另一个固定位置。

句中的过去分词 required 作定语，修饰名词短语 the two limits。

[5] The magnitude of the differential gap must be determined from such considerations as the accuracy required and the life of the component.

差动间隙的大小必须根据要求的精度和元件的寿命等因素来确定。

句中的过去分词 required 作定语，修饰名词 the accuracy。

[6] The derivative control action, sometimes called rate control, is where the magnitude of the controller output is proportional to the rate of change of the actuating error signal.

微分控制作用有时也叫作速率控制，是控制器输出值中和误差信号变化的速率成正比的部分。

句中的过去分词短语 sometimes called rate control 作定语，修饰主语 The derivative control action。where 引导的是表语从句。

[7] Since the dynamic and static characteristics of the measuring element affect the indication of the actual value of the output variable, the measuring element plays an important role in determining the overall performance of the control system.

由于测量元件的动态和静态特性影响输出变量的实际测量值，因而在决定控制系统的整体性能时，测量元件具有很重要的作用。

[8] A block diagram of a simple automatic control system may be obtained by connecting the plant to the automatic controller, as shown in Fig. 7.1.

简单的自动控制系统的方块图可以通过把对象与控制器连接起来而得到，如图 7.1 所示。

句中的 as shown in Fig. 7.1 作定语，修饰整个句子。

Translating Skills　句子的分译与合译

英汉两种语言的句子结构区别很大。英语重形合，句子结构主要靠语法手段进行搭架，结构严谨。句子以主语、谓语为基础，借助介词、连词、连接词或短语、关系代词和关系副词等一层层严密地把句子穿起来，句中只能有一个谓语动词。汉语重意合，句子结构往往按照句内的逻辑、时间、空间和心理等顺序层层展开，一个句子可有多个动词连用。因此翻译有些句子时常常需要将原来的句子结构作较大的改变，以适应汉语的表达习惯。常用的两种方法包括分译和合译。

分译

分译就是把原句的某些成分分出来另外翻译，译成汉语的独立的句子，使译文意思简明，层次清楚，符合汉语习惯。

1. 分译副词

(1) He, **not surprisingly**, did not hand in his homework.
他没有交作业，**这是不足为奇的**。

(2) **Incidentally**, I have bought that book.
顺便说一句，我已经买了那本书。

(3) **Strange enough,** they are the same age to the day.
说来也真巧，他俩年纪一样大，而且还是同日生的。

2. 分译形容词

(4) His music was an **exciting** mixture of white country and black blues.
他演唱的音乐把白人的乡村音乐和黑人的“布鲁斯”音乐融为一体，**非常激动人心**。

(5) He spoke with **understandable** pride of the invention of the instrument.
他谈到那种仪器的发明时很自豪，**这一点是可以理解的**。

3. 分译名词

(6) A **move** of me leaving that foxhole would look like a shell leaving a rifle.
我离开那个单人掩体速度之快，**要实拍成电影的话**，会像出膛的子弹一样。

(7) **Beggars** must not be choosers.
(既然是)**要饭的**，就必不会挑肥拣瘦。

4. 分译介词短语

(8) They danced on **through the night.**
他们翩翩起舞，**通宵达旦**。

(9) Amplitude modulation is accomplished **by impressing the audio wave from the microphone on the carrier wave.**

把电话的音频波加到载波上，则实现调幅操作。

(10) No body at rest can be set in motion **without a force being acted upon it.**

没有外力的作用，静止的物体不可能开始运动。

(11) They held the fort **against all attacks**.

他们坚守堡垒，**抵抗所有的运动。**

5. 分译分词短语

(12) He walked down the line **shaking hands with each** and **mumbling a few words** that were inaudible.

他走过列队**，与人们一一握手，嘴里咕哝着几句什么话，**谁也听不清。

(13) **Taking the example of a microphone as an initial source again** a typical source impedance will be around 100 Ohms.

仍以麦克风为初始信号源为例，典型的源阻抗在 100 欧左右。

6. 分译动词不定式

(14) Several persons went to the canteen **to dance.**

几个人走进食堂，**跳起舞来。**

(15) **To feel well again,**they must be allowed to dream.

要恢复健康，就得让他做梦。

(16) Many practical amplifiers chain together a series of analog amplifier stages **to obtain a high overall voltage gain.**

许多实际的放大器将多个放大器级联起来，**以获得较高的电压增益**。

7. 分译状语成分

(17) **Science and technology modernized**, industry and agriculture will develop rapidly.

如果科学技术现代化了，工农业就会迅速发展。

8. 分译名词化结构

(18) Evening had come, **the last of Adolf Hitler's life.**

夜晚已经来临，**这是阿道夫· 希特勒生命中最后的一个夜晚。**

(19) The signal levels inside power amplifiers are so much larger than these weak inputs that **even the slightest "leakage" from the output back to the input** may cause problems.

功率放大器中的信号幅度比微弱的输入信号大得多，**即使输出的极微小的泄漏传输到输入端**，都会引发一些问题。

(20) **An inferior pilot** in such a situation would inevitably have lost his head.

换一个差一点的飞行员，遇到这种情况，就一定不知所措了。

9. 把一个句子分译成两个以上的句子

(21) **His failure to observe the safety regulations** resulted in an accident to the machinery.

因为它没有遵守安全规则，结果机器出了故障。

(22) Einstein and Marie became friends in 1896 **while studying together at the Federal Technical Institute in Zurich.**

爱因斯坦与玛丽克是在 1896 年成为朋友的。**当时他俩正在苏黎士的联邦理工学院学习**。

(23) Note the negative sign in expression 1-1 which indicates **that the examples all invert the signal pattern when amplifying.**

注意，表达式 1−1 中的负号表明，**示例中的电路在放大时改变了信号的极性。**

(24) Their name is derived by the fact that **they are used for performing mathematical operations on their input signal(s) .**

运放用于对输入的信号进行数学运算，故此而得名。

10. 分译定语从句

(25) His bride apparently had no appetite for lunch that day, and Hitler took his meal with his two secretaries and with his vegetarian cook, **who perhaps did not realize that she had prepared his last meal.**

那天他的新娘显然没有胃口用午餐，希特勒与他的两名秘书以及那位烹调素食的厨师一起进餐。**厨师或许还不知道，他准备的是希特勒的最后一餐。**

(26) The following experiment provides evidence **which supports the above finding.**

下面的试验提供证据，**证实了上面的研究结果**。

合译：当英语的两个或两个以上的英语简单句关系密切、意义贯通时，可把英语的两个以上的简单句合译成一个汉语的简单句或复句；当英语的主从复合句或并列复合句的句子结构和汉语的句子结构不一致时，把英语的主从复合句或并列复合句合译成汉语的一个简单句。

(27) The more he tries to conceal his warts, the more he reveals them.

欲盖弥彰。

(28) There are many people who are applying for the job.

许多人在申请这份工作。

(29) He would miss his country. He would miss his mother and father.

他会想念祖国、父母。

(30) The Post Office was helpful, and Marconi applied in June 1896 for the world’s first radio patent.

在英国邮局帮助下，马可尼于 1896 年 6 月申请了世界第一项无线电专利。

Exercises

1. Translate the following into Chinese.

(1) Pneumatic controllers which do not have feedback mechanisms (which means that one end of the flapper is fixed) have high sensitivity and are called narrow-band proportional controllers or two- position controllers.

(2) Regardless of how differently industrial pneumatic controllers may appear, careful study will show the close similarity in the functions of the pneumatic circuit.

(3) Such common methods as windows sockets, web server, and web services would allow

almost every computer around the world be able to access and use the information provided they have the correct permissions.

(4) For example, your users might prefer that you put the results into an Excel spreadsheet or database so that they can use their own tools for creating the report.

(5) The climate remains the same, independent of the season of the year.

(6) There are three forms of heat transfer: heat conduction, convection(对流)，and radiation.

(7) International communication facilities are provided for passengers in our hotel.

2. Translate the following into English.

(1) 假定变量的幅度足够小，系统就可以近似用一个线性数学模型-传递函数表示。

(2) 除了低压气动控制器以外，压缩空气很少被用于外部负荷力作用下具有很大质量的设备运动的连续控制。

(3) 函数就是两组元素一一对应的规则，第一组中的每个元素在第二组中只有唯一的对应量。

(4) PID 控制器是工业过程控制中使用得最为广泛的控制器。

(5) 她身体健壮(sturdy) ，容貌美丽，既节俭又明理。

(6) 毫无疑问，广泛地使用新的公交系统(transit systems)能够减少空气污染。

(7) 据美国国家气象局(weather bureau)报道，每年有 73 人因被闪电击中而死亡，另有数百人的生命和健康受到损害。

Reading Material Introductions to SCADA

A SCADA system or Supervisory Control and Data Acquisition system has such features as computer based, alarms, data acquisition, operator interface, non real-time control, database and log files, reports and information sharing, etc.

Computer Based. We feel that SCADA software must have all possible types of connectivity and integration. This means serial ports, Ethernet, PCI slots, and the ability to run a wide variety of applications. PLCs and simple operator interfaces (i.e. not based on the regular Windows operating system) are too limited in their functionality and capabilities.

Alarm and Event Monitoring. A SCADA system must be able to detect, display, and log alarms and events. When there are problems the SCADA system must notify operators to take corrective action. Alarms and events must be recorded so engineers or programmers can review the alarms to determine what caused the alarm and prevent them from happening again.

Data Acquisition. SCADA must be able to read data from PLCs and other hardware and then analyze and graphically present that data to the user. SCADA systems must be able to read and write multiple sources of data.

Operator Interface. A SCADA system collects all of the information about a process. The SCADA system then needs to display the data to the operator so that they can comprehend what is going on with the process.

Non Real-Time Control. For simple control requirements, the SCADA system should be able to perform control instead of a PLC. However, for anything other than simplistic control we prefer a PLC or soft PLC to do the real-time control with SCADA doing the non real-time control. The SCADA system is the medium between the operator and the real-time controller. It allows the operator to control the system, such as start a new batch, load a new recipe, etc.

Databases and Data Logging. Most applications require recipes, data logging, and other means of reading and writing databases. The great thing about SCADA systems is that they can log incredible amounts of data to disk for later review. This is helpful for solving problems as well as providing information to improve the process. Many different methods should be available, including plain text, binary fixed column, Comma Separated Variable (CSV) , XML, Excel, Access, SQL, SQL Server, ODBC, web services.

Reports and Information Sharing. What good a SCADA system and all this information if you can't share it with others is? Some of the reports overlap with the previous description of databases and data logging. For example, your users might prefer that you put the results into an Excel spreadsheet or database so that they can use their own tools for creating the report. Or the users might want you to create reports in Microsoft Word format.

You also must share data with other users. Such as windows sockets, web server, and web services. These three methods would allow almost every computer around the world be able to access and use the information provided they have the correct permissions.

New Words and Phrases

1. log [lɔg]	n.	航行日志，记录，日志，原木，园木
	v.	把……记入航行日志，伐木，把……锯成段
2. slot [slɔt]	n.	缝，狭槽，插槽，位置，水沟，细长的孔，硬币投币口，狭通道，足迹
	vt.	开槽于，跟踪
3. recipe [ˈresipi]	n.	处方，烹饪法，食谱，配方，制法，秘方，秘诀

4. XML abbr. Extensible Markup Language　　可扩展标记语言
5. SQL abbr. Structured Query Language　　结构化查询语言
6. ODBC abbr. [计] Open Database Connectivity　　开放式数据库连接性

7. socket [ˈsɔkit]	n.	[计]套接字，窝，穴，孔，插座，牙槽
	vt.	给……配插座

Lesson 8 System Design and Compensation Techniques

Control systems are designed to perform specific tasks. The requirements imposed on the control system are usually referred as performance specifications. They generally relate to accuracy, relative stability and speed of response.

Generally, the performance specifications should not be more stringent than necessary to perform the given task. If the accuracy at steady-state operation is of prime importance in a given control system, then we should not require unnecessarily rigid performance specifications on the transient response since such specifications will require expensive components. We should remember that the most important part of control system design is to state the performance specifications precisely so that they will yield an optimal control system for a given purpose. [1]

In this lesson, we are going to briefly introduce the design and compensation procedure of single-input-single-output (SISO) , linear time-invariant (LTI) control systems by the frequency response and root-locus approaches. Compensation is the modification of the system dynamics to satisfy the given specifications.

Setting the gain is the first step in adjusting the system for satisfactory performance. In many cases, increasing the gain value will improve the steady-state behavior but will result in poor stability or even instability. Then it is necessary to redesign the system (by modifying the structure or by incorporating additional devices or components) to alter the overall behavior so that the system will behave as desired.

Fig. 8.1 shows the configuration where the compensator $G_C(s)$ is placed in series with the plant. This scheme is called series compensation. Another kind of compensation is feedback compensation. Generally, series compensation may be simpler than feedback compensation.

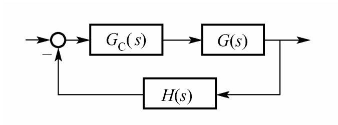


Fig. 8.1 Series compensation

In discussing compensators, we frequently use terminology as lead network, lag network, and lag-lead network. If a sinusoidal input e_i is applied to the input of a network and the steady-state output e_o (which is also sinusoidal) has a phase lead, then the network is called a lead network. Similarly, if the steady-state output e_o has a phase lag, then the network is called a lag network. In a lag-lead network, phase lag and phase lead both occur in the output but in different frequency regions; phase lag occurs in the low-frequency region and phase lead occurs in the high-frequency region.

Root-locus approach to control system design

The root-locus method is a graphical method for determining the locations of all closed-loop poles from knowledge of the locations of the open-loop poles and zeros as some parameter (usually the gain) is varied from zero to infinity. The method yields a clear indication of the effects of parameter adjustment. In practice, the root-locus plot of a system may indicate that the desired performance cannot be achieved just by the adjustment of gain. Then it is necessary to reshape the root loci to meet the performance specifications.

In designing a control system, we may modify the original root loci by inserting a suitable compensator $G_C(s)$ (as shown in Fig.8.1). Once the effects on the root locus of the addition of the poles and/or zeros are fully understood, we can readily determine the locations of the pole(s) and zero(s) of the compensator that will reshape the root locus as desired. [2] In the design by the root-locus method, the root-loci of the system are reshaped through the use of a compensator so that a pair of dominant closed-loop poles can be placed at the desired locations. (Usually, the damping ratio and undamped natural frequency may be specified by the locations of a pair of dominant closed-loop poles.) [3]

The addition of a pole to the open-loop transfer function has the effect of pulling the root locus to the right, tending to lower the system's relative stability and to slow down the settling of the response. [4] The addition of a zero has the effect of pulling the root locus to the left, tending to make the system more stable and to speed up the settling of the response.

The root-locus approach to design is very powerful when the specifications are given in terms of time domain quantities, such as the damping ratio and undamped natural frequency, maximum overshoot, rise time and settling time.

Let us consider a design problem. The original system either is unstable for all values of gain or is stable but has undesirable transient response characteristics. In this case, the reshaping of the root locus is necessary in order that the dominant closed-loop poles be at desired locations in the complex plane. Inserting an appropriate lead compensator in cascade with the feed-forward transfer function may solve this problem. [5]

Frequency-response approach to control system design

It is important to note that in a control system design, transient-response performance is usually most important. In the frequency-response approach, we specify the transient-response in terms of the phase and gain margin, resonant peak magnitude, the gain crossover frequency, resonant frequency and bandwidth. [6] Although the correlation between the transient response and frequency response is indirect, the frequency domain specification can be met conveniently by means of Bode diagram.

Design in the frequency domain is simple and straightforward. After the open loop has been designed by frequency response method, the closed loop poles and zeros can be determined. The transient response characteristics must be checked to see whether the designed system meets the requirements in the time domain. If it does not, the compensator has to be modified and the analysis must be repeated until a satisfactory result is obtained.

Basically, there are two approaches in the frequency-domain design. One is the polar plot approach and the other is the Bode diagram approach. It is more convenient to work with Bode diagram. A Bode diagram of the compensator can be simply added to the original Bode diagram, and thus plotting the complete Bode diagram is a simple matter.[7] Also, if the open loop gain is varied, the magnitude curve is shifted up or down without changing the slope of the curve, and the phase curve remains the same.

A common approach to the Bode diagram is that we first adjust the open loop gain so that the requirement on the steady state accuracy is met. Then we plot the magnitude and phase curves of the uncompensated open loop. If the specification on the phase margin and gain margin are not satisfied, then a suitable compensator that will reshape the open loop transfer function is determined.

In many practical cases, compensation is essentially a compromise between steady-state accuracy and relative stability. In order to have a high value of the velocity error constant and yet satisfactory relative stability, we find it necessary to reshape the open loop frequency response curve. The gain in the low-frequency region should be large enough to satisfy the steady-state accuracy requirements. For the medium-frequency region (near the gain crossover frequency ω_C from both directions) , the slope of the log-magnitude curve in the Bode diagram should be −20 dB per decade.[8] This slope should extend over a sufficient wide frequency band to assure a proper phase margin. For the high-frequency region, the gain should be attenuated as rapidly as possible to minimize the effects of noise.

The basic characteristics of lead, lag, and lag-lead compensation are as following. Lead compensation essentially yields an appreciable improvement in transient response and a small change in steady-state accuracy. It may accentuate high-frequency noise effects. On the other hand, lag compensation yields an appreciable improvement in steady-state accuracy at the expense of increasing the transient-response time. Lag compensation will suppress the effects of high-frequency noise signals. Lag-lead compensation combines the characteristics of both lead compensation and lag compensation.

New Words and Phrases

1. compensation [kɔmpenˈseiʃ ən]	n.	补偿，调整，校正
2. impose [imˈpəuz]	v.	将……强加于，施加，使……负担
3. stringent [ˈstrindʒənt]	adj.	严厉的，迫切的
4. root-locus [ˈruːt-ˈləukəs]	n.	(pl. root-loci) 根轨迹
5. indication [indiˈkeiʃ ən]	n.	指示，指出，显示，暗示
6. transient [ˈtrænziənt]	adj.	暂态的，瞬时的，过渡过程的

7. magnitude [ˈmægnitjuːd]	n.	量值，幅度
8. straightforward [streitˈfɔːwəd]	adj.	直截了当的
9. accentuate [ækˈsentjueit]	v.	加强，强调
10. attenuate [əˈtenjueit]	v.	削弱
11. approach [əˈprəutʃ]	n.	方法，途径
12. characteristic [ˌkæriktəˈristik]	n.	特性，特征
	adj.	特有的，典型的
13. prime [praim]	n.	最初，青春，精华
	adj.	主要的，最初的，有活力的，最好的，根本的，素数的
14. rigid [ˈridʒid]	adj.	刚硬的，刚性的，严格的，坚硬的，僵直的，坚决的，固定的
15. transient response		暂态响应，过渡反应，瞬时 [瞬态] 反应，瞬时反应特性，瞬时特性
16. yield [jiːld]	vt.	出产，产生，生长，生产 vi.(～to) 屈服，屈从，放弃
	n.	产量，收益
17. time-domain		时域的
18. overshoot [ˈəuvəˈʃuːt]	vt.	打过头，飞过目标，超过，越过
	vi.	射击越标，行动过火
	n.	超调量
19. settling time		调整时间
20. phase margin		相位裕量
21. gain margin		增益裕度
22. resonant [ˈrezənənt]	adj.	(引起)共鸣的，响亮的，共振的，深沉的
23. perk [pəːk]	vi.	昂首，恢复，振作
	vt.	竖起，打扮
24. resonant perk value		谐振峰值
25. bandwidth [ˈbændwitθ]	n.	带宽，频带宽度

Notes

[1] We should remember that the most important part of control system design is to state the performance specifications precisely so that they will yield an optimal control system for a given purpose.

我们应该牢记，控制系统设计过程中最重要的一个环节就是把性能要求精确地表达出来，这样才会设计出对于给定的目的而言最优的控制系统。

本句的结构比较复杂。在 remember 后面 that 所引导的从句是宾语从句，在该从句中“to state…”是从句中的表语从句。在翻译这种英语长句时，不能够拘泥于原句的语法结

构，而应该在充分理解该语句意思的基础之上，重新组织，再用通顺的汉语表达出来。如果过分拘泥于原来的语法结构，则翻译出来的汉语不通顺。科技英语翻译就是要在尽可能忠实于原文的基础上，将通顺的英语(或汉语)所表达的意思转换成用通顺的汉语(或英语)表达。

[2] Once the effects on the root locus of the addition of the poles and/or zeros are fully understood, we can readily determine the locations of the pole(s) and zero(s) of the compensator that will reshape the root locus as desired.

一旦我们完全理解了增加极点和/或零点对于根轨迹的影响，我们就可以很方便地确定补偿器零点和极点的位置，以使得根轨迹改变成为我们所希望的形状。

Once 引导条件状语从句，而且该条件状语从句是用被动语态。Compensator 后面的 that…引导定语从句修饰 the pole(s) and zero(s) of the compensator。

[3] In the design by the root-locus method, the root-loci of the system are reshaped through the use of a compensator so that a pair of dominant closed-loop poles can be placed at the desired locations. (Usually, the damping ratio and undamped natural frequency may be specified by the locations of a pair of dominant closed-loop poles.)

在用根轨迹法设计的过程中，通过使用补偿器改变系统根轨迹的形状，以使闭环系统一对主导极点位于理想的位置。(通常，阻尼比和无阻尼自然振荡频率是由闭环系统一对主导极点的位置确定的。)

本句中有两个状语，In the design by…介词短语作状语表示场合；而 so that a pair of…状语从句表示结果。

[4] The addition of a pole to the open-loop transfer function has the effect of pulling the root locus to the right, tending to lower the system’s relative stability and to slow down the settling of the response.

在开环传递函数中增加一个极点的效果是把根轨迹向右推，倾向于降低系统的相对稳定性，并且降低系统的收敛速度。

介词短语 The addition of a pole to the open-loop transfer function 是句子的主语，现在分词短语 tending to lower…作状语，表示伴随状态。

[5] Inserting an appropriate lead compensator in cascade with the feed-forward transfer function may solve this problem.

在前向传递函数中串联插入一个适当的超前补偿器，就可以解决这个问题。

动名词短语 Inserting an…是句子的主语。

[6] In the frequency-response approach, we specify the transient-response in terms of the phase and gain margin, resonant peak magnitude, the gain crossover frequency, resonant frequency and bandwidth.

在频率响应法中，我们以相位裕量及增益裕量、谐振峰值幅度、增益穿越频率、谐振频率和带宽来表征暂态响应。

在这个句子中，the phase and gain margin, resonant peak magnitude, the gain crossover frequency, resonant frequency and bandwidth 并列成为介词短语 in terms of 后面的宾语。

[7] A Bode diagram of the compensator can be simply added to the original Bode diagram,

and thus plotting the complete Bode diagram is a simple matter.

补偿器的伯德图可以简单地加在原伯德图上，因此画完整的伯德图是很简单的事。

句子中 and thus plotting…是一个并列句，其中动名词短语 plotting the complete Bode diagram 作主语。

[8] For the medium-frequency region (near the gain crossover frequency ω_C from both directions) , the slope of the log-magnitude curve in the Bode diagram should be −20 dB per decade.

在中频段(靠近幅频曲线的穿越频率 ω_C 的两边)，在伯德图中对数幅值曲线的斜率应该为−20 dB/dec。

本句中括号内的部分是介词短语作为定语，用来修饰 region。

Translating Skills　数词的译法

在专业英语中，数词出现的频率很高，对数词的翻译及读法的掌握程度会影响对专业的学习、研究及交流。现分别介绍一些专业英语中常用的数词的译法和数学符号、公式的读法。

1. 基数词的译法和读法

(1) 从 1 到 12 是单个单词：	十一　11 eleven	十二　12 twelve
(2) 从 13 到 19 加后缀-teen：	十三　13 thirteen	十九　19 nineteen
(3) 从 20 到 90 加后缀-ty：	二十　20 twenty	二十三 23 twenty-three
	九十　90 ninety	

百位数以上：

五百	500 five hundred
五百六十一	561 five hundred (and) sixty-one
五千六百六十一	5,661 five thousand six hundred (and) sixty-one

2. 序数词的译法和读法

序数词翻译时加“第……”，如 twelfth 12th 第十二　　thirtieth　30th　第三十

3. 数词的增加和减少的译法和读法

(1) The oxygen atom **is** nearly **16 times** heavi**er than** the hydrogen atom.

氧原子的重量几乎是氢原子的 **16 倍**。(如果把 16 用 *n* 代替，常译作“是……的 *n* 倍，或“比……(大、多、长)*n*−1 倍”)

(2) The diode produces **5 times more** radiant power **than** that one.

这只二极管的辐射功率比那只**大 4 倍**(是那只的 5 倍)(同上)。

(3) The wire is **twice as long as** that one.

这根电线的长度是那根的**两倍**。(如果把 twice 用 *n* 代替，常译作“是……的 *n* 倍，或“比……(大、多、长)*n*−1 倍”)

(4) The production of air-conditioners has **increased three times** this year.

今年空调的产量增加 2 倍(**增加到 3 倍**)。(如果句中 three 用 n 表示，那么常译成“增加了 n−1 倍或增加到 n 倍”)

(5) The production of air-conditioners **has increased by three times** over the previous year.
今年空调的产量比上一年**增加了 3 倍。**

(6) The production of air-conditioners **has decreased by three times** over the previous year.
今年空调的产量比上一年**减少了 3 倍。**

(7) The production of air-conditioners **has increased to three times** this year.
今年空调的产量**增加到了 3 倍。**

(8) The production of air-conditioners **has increased by a factor of three times** this year.
今年空调的产量增加 2 倍。(如果句中 three 用 n 表示，那么常译成“增加了 n−1 倍”
类似减少的译法有：

(1) reduce by 10%	减少了 10%
(2) reduce to 10%	减少到 10%
(3) reduce by a factor of 10	减少了 9/10(减少到 1/10)
(4) reduce 10 times	减少到 1/10(减少了 9/10)

4.分数、小数、时间等的译法和读法

(1) 简单的分数。

1/7	七分之一	one seventh	3/4	四分之三	three quarters
1/4	四分之一	a/one quarter	1/2	二分之一	a/one half
$4\frac{1}{2}$	四又二分之一	four and a half	$3\frac{4}{5}$	三又五分之四	three and four-fifths

(2) 复杂的分数。

24/9	九分之二十四	twenty-four over nine
20/83	八十三分之二十	twenty over eight three (twenty eighty-thirds)
7/20	二十分之七	seven twentieths
67/200	二百分之六十七	sixty-seven two hundredths

(3) 小数。

0.124	零点一二四	(nought) point one two four
0.24	零点二四	(nought) point two four
0.4	零点四	(nought) point four
16.789	十六点七八九	one six point seven eight nine

(4) 时间或其他。

60 年代初期	in the early sixties
本世纪 90 年代	in the nineties of the century

20 世纪 90 年代(1990s, 1990’s) nineteen nineties

2005 年 10 月 10 日 October 10th, 2005 (10 th October, 2005/ October 10, 2005/ 10 October 2005)

Fig.7 图 7(直译)

14′59.38″十五分五十九点三八秒 fourteen minutes fifty-nine point three eight seconds

5. 数学符号、公式的读法

+	加(上)	plus/and
−	减(去)	minus
×	乘以	times; multiplied by
÷	除以	divided by/divided
=	等于	is equal to/equals
≈	大约等于	is approximately equal to
( )	圆括号	round brackets/parentheses
[ ]	方括号	squared brackets
/	斜杠	slash
65%	百分之六十五	65 percent
10^9	十的九次方	the ninth power of ten/ten to the power nine/ten to the ninth power
10^{-5}	十的负五次方	en to the minus five
x'		*x* prime
x''		*x* second prime
x_e		*x* sub *e*
$\sqrt{2}$	根号 2	the square root of 2
⩾	大于或等于	is more than or equal to
⩽	小于或等于	is less than or equal to
＞	大于	is more than
δ		delta
Φ		Phi
Ω		omega
ε		epsilon
∝	与……成比例	varies as/ is proportional to
ω		omega
5 mm	5 毫米	5 millimeters
$x \to \infty$		x approaches to infinity

Exercises

1. Translate the following into Chinese.

(1) Generally, we should adopt reasonable performance specifications while we are designing a control system.

(2) We often use lead network, lag network, or lag-lead network to work as compensators in control system compensation.

(3) Compensation for a closed-loop control system is essentially a compromise between steady-state accuracy and relative stability of the system.

(4) The substance reacts three times as fast as the other one.

(5) The students who take part in physical activities have increased to 10,000.

(6) One in five women born in 1970 has suffered from depression and anxiety in their thirties, twice the rate of those born in 1940, the University of London has found.

2. Translate the following into English.

(1) 使用根轨迹法设计控制系统补偿器，就是为了使闭环系统的一对主导极点位于左半 S 平面中的理想位置。

(2) 超前补偿可以明显改善控制系统的暂态响应，对稳态精度没有影响。

(3) 用伯德图设计的常用方法是，我们首先调节开环增益，以使稳态精度的要求得到满足。

(4) 那位警察要了比平常多一倍的罚款。

(5) 去年钢产量减少了 20%。

(6) 这家造纸厂的产量比 1980 年增加两倍。

Reading Material An Eye on Reactor and Computer Control

A nuclear power plant operator stared at the computer screen and yawned. As the end of a long shift approached, he was feeling very tired as he looked at icons of pumps, pipes, and turbines. Even so, it was still early in the reactor startup sequence. When an indication that the reactor had gone critical appeared on the screen, the operator tried to rouse himself. There was no need for him or anyone else to be alarmed, however. Based on the way the operator looked at the screen, the computer had already sensed that he was tiring and had begun to assist the operator in reactor control. The computer zoomed in on the displays the operator needed to monitor reactivity and highlighted the important data. It would even be capable of assuming partial reactor control if necessary.

At a research laboratory, a cognitive scientist put a diskette in her computer and studied the screen. The data indicated that a reactor operator had been glancing at a number of widely scattered points in a short time on the computer screen in the reactor control room. “All these eye movements,” said the scientist, “tell me the operator is experiencing excessive mental work load. It seems that several displays associated with reactor control must be redesigned to make it easier for the operator to understand quickly what’s going on.”

A teenager who lost the use of both hands as a result of an automobile accident had found a way to write again. His father bought him an “eye typewriter”——a computer that displays and prints letters from a display of the alphabet on the screen in the order in which they are stared at. The boy enjoyed his ability to control a computer simply by looking at it.

These futuristic scenarios suggest that information on eye gazes——the way people look at an object——can be put to use to determine a person’s mental work load and level of fatigue, to guide the design of computer displays to speed human processing of information, and to control computers. Other applications include controlling camera positions on robots and guiding an artificial intelligence system in recognizing enemy targets.

At ORNL computer software has been developed to make possible an improved eye-gaze measurement technology. Such an innovation could be the basis for advanced eye-gaze systems that may have applications such as those mentioned above.

New Words and Phrases

1. yawn [jɔːn]	v. n.	打哈欠，哈欠
2. turbine [ˈtəːbin]	n.	涡轮机
3. critical [ˈkritikəl]	adj.	危急的，临界的
4. scatter [ˈskætə]	v.	分散，散开，驱散
5. innovation [ˌinəuˈveiʃən]	n.	改革，创新
6. zoom in		(镜头)放大

Lesson 9 Nonlinear Control Systems

Many different types of nonlinearities may be found in practical control systems, and they may be divided into two classes, depending upon whether they are inherent in the system or intentionally inserted into the system.[1]

In what follows, we shall first discuss inherent nonlinearities and then intentional nonlinearities. Then we shall discuss approaches to the analysis and design of nonlinear control systems.

A differential equation that describes a system is shown as:

$$k_n x^{(n)} + \cdots + k_2 \ddot{x} + k_1 \dot{x} + k_0 x = u(t) \tag{9-1}$$

If all the coefficients $k_n, \cdots, k_0$ are constants, the system is a Linear Time Invariant (LTI) system. If one or more of $k_n, \cdots, k_0$ is a function of the dependent variable *x* or its derivatives, the system is a nonlinear system. And if one or more of $k_n, \cdots, k_0$ is a function of independent variable *t*, the system is time-variant system.[2]

The principle of superposition does not apply to nonlinear systems. As a result, the analysis and design techniques discussed so far for LTI systems, including the use of transfer functions and Laplace transforms, are no longer valid.[3] Even worse, there is no general equivalent technique to replace them. Instead, a number of techniques exist, and each is of limited applications. In this lesson, we are going to introduce the phase-plane and describing function methods briefly.

It is important to be aware of the differences between LTI systems and nonlinear systems. The nonlinear systems often have following features:

1. The nature of the response depends on input and initial conditions. For example, a nonlinear system can change from stable to unstable, if the size of a step input is doubled.

2. Instability shows itself frequently in the form of limit cycles. The limit cycles are oscillations with fixed amplitude and frequency that can be sustained in the feedback loop even if the system input is zero.

3. The steady-state response to a sinusoidal input can contain harmonics and sub-harmonics of the input frequency.

The commonly encountered types of nonlinearity are shown in Fig. 9.1, with x as input and y as output. These are inherent in some elements of control systems.

Some nonlinear elements are intentionally introduced into a system in order to improve the system performance or to simplify the construction of the system, or both. The simplest example of such an intentionally nonlinear system is a conventional relay-operated system. Other examples may be found in optimal control systems that often employ complicated nonlinear controllers. It should be noted that although intentional nonlinear elements may improve the system performance under certain specified operating conditions, they will, in general, degrade system performance under other operating conditions.[4]

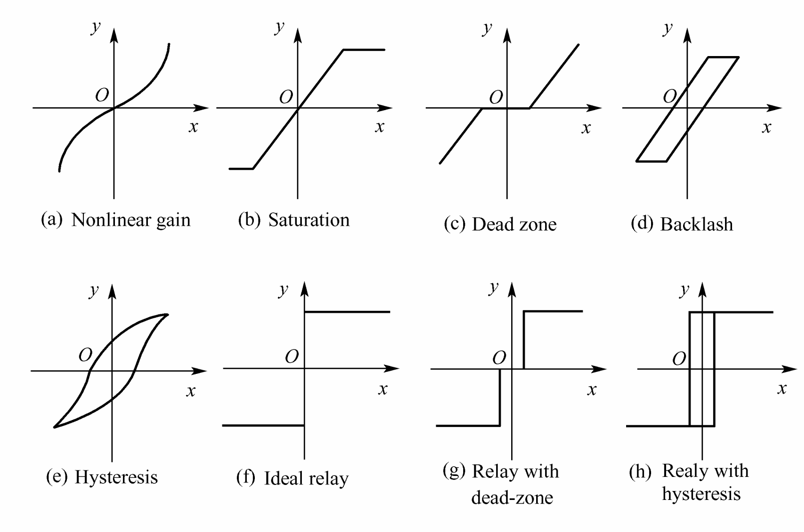


Fig. 9.1　Commonly encountered nonlinearities

Phase-Plane Method

The phase-plane method is a graphical method to find the transient response of first or second order systems. Considering the following nonlinear equation：

$$\ddot{x}+g(x,\dot{x})\dot{x}+h(x,\dot{x})x=0 \tag{9-2}$$

Let $y=\dot{x}$, then we have $\ddot{x}=\dot{y}=\dfrac{\mathrm{d}y}{\mathrm{d}x}\cdot\dfrac{\mathrm{d}x}{\mathrm{d}t}=\dfrac{\mathrm{d}y}{\mathrm{d}x}\cdot\dot{x}=y\cdot\dfrac{\mathrm{d}y}{\mathrm{d}x}$. Substitute them into equation (9-2) :

$$y\cdot\frac{\mathrm{d}y}{\mathrm{d}x}+g(x,y)y+h(x,y)x=0 \tag{9-3}$$

Rearranging equation (9-3) yields the phase-plane equation.

$$\frac{\mathrm{d}y}{\mathrm{d}x}=\frac{-g(x,y)y-h(x,y)x}{y} \tag{9-4}$$

The phase plane plot is a plot of y versus x. At each point (x , y) , $\mathrm{d}y/\mathrm{d}x$ is the slope of the trajectory through that point.

Isoclines are loci of constant trajectory slopes. The isocline equation for $\mathrm{d}y/\mathrm{d}x=m$ is

$$y=\frac{-h(x,y)x}{g(x,y)+m} \tag{9-5}$$

The graphical technique is called the isocline method, and is useful to sketch the phase-plane trajectories.

Describing Function

The describing function technique is a response method, and its main usage is in stability analysis (i.e., the prediction of limit cycles) In Fig. 9.2, G_1 and G_2 represent linear parts of the system and N a nonlinear element.

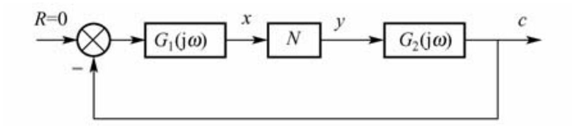


Fig. 9.2 A nonlinear system

The model for N in Fig. 9.2 used in this analysis is based on the assumption: that the input x to the nonlinear element is a sinusoidal signal.

$$x = A\sin\omega t \tag{9-6}$$

The output of the nonlinear element is a periodical signal of the same frequency as input. By neglecting the harmonics of y, we may define the describing function as:

$$N(A) = \left|N(A)\right| \mathrm{e}^{j\angle N(A)} = \frac{Y_1}{A}\mathrm{e}^{\mathrm{j}\phi_1} \tag{9-7}$$

The characteristic equation of the system becomes:

$$G_1(s)G_2(s) = -1/N(A) \tag{9-8}$$

The Nyquist stability criterion for the control system with a nonlinear element will be changed accordingly. The describing-function method provides stability information for a system of any order, but it will not give exact information as to the time-response characteristics.[5]

New Words and Phrases

1. inherent	[inˈhiərənt]	adj.	固有的，内在的
2. nonlinearity	[ˌnɔnliniˈæriti]	n.	非线性（特性）
3. intentionally	[inˈtenʃənəli]	adv.	有意地，故意地
4. differential equation			微分方程
5. be aware of			意识到，知道，注意到
6. feature	[ˈfiːtʃə]	n.	特征，特点
7. limit cycle			极限环
8. initial condition			初始条件
9. oscillation	[ˌɔsiˈleiʃən]	n.	振荡，振动
10. amplitude	[ˈæmplitjuːd]	n.	振幅
11. sustained	[səsˈteind]	adj.	持续的
12. encounter	[inˈkauntə]	v. n.	遭遇，遇到，相遇
13. harmonics	[hɑːˈmɔniks]	n.	谐波，和声
14. conventional	[kənˈvenʃənl]	adj.	常规的，传统的
15. complicated	[ˈkɔmplikeitid]	adj.	复杂的，难解的

16. describing function		描述函数
17. substitute [ˈsʌbstitjuːt]	v.	代换，代替
18. assumption [əˈsʌmpʃən]	n.	假设
19. criterion [kraiˈtiəriən]	n.	(pl. criteria)判据，标准，指标
20. isoclinic [ˌaisəuˈklinik]	adj.	等倾斜的
21. isocline method		等倾线法
22. neglect [niˈglekt]	v. n.	忽略，忽视
23. characteristic [ˌkæriktəˈristik]	adj.	特有的，特征的；
	n.	特性，特征
24. accordingly [əˈkɔːdiŋli]	adv.	相应地，从而，因此
25. be inherent in		为……所固有，是……的固有性质，生来的

Notes

[1] Many different types of nonlinearities may be found in practical control systems, and they may be divided into two classes, depending upon whether they are inherent in the system or intentionally inserted into the system.

在实际控制系统中存在许多种不同类型的非线性。根据它们是系统本身内在的，还是人为故意加入系统中的，这些非线性可以分为两类。

句中 depending upon…是分词复合结构作条件状语。

[2] If one or more of $k_n,\cdots,k_0$ is a function of the dependent variable x or its derivatives, the system is a nonlinear system. And if one or more of $k_n,\cdots,k_0$ is a function of independent variable t, the system is time-variant system.

如果$k_n,\cdots,k_0$中有一个或者一个以上是变量x或其各阶导数的函数，则系统为非线性系统。并且，如果$k_n,\cdots,k_0$中有一个或者一个以上是自变量t的函数，则系统是时变系统。

句中 dependent variable 指的是因变量，而 independent variable 是自变量。

[3] The principle of superposition does not apply to nonlinear systems. As a result, the analysis and design techniques discussed so far for LTI systems, including the use of transfer functions and Laplace transforms, are no longer valid.

叠加原理不适用于非线性系统。因此，到目前为止我们所讨论的关于线性定常系统的分析和设计方法，包括使用传递函数和拉普拉斯变换，都不再有效。

句中 discussed so far…是过去分词短语作定语修饰 techniques，而 including the use…是现在分词短语作插入语，同样也是修饰 techniques。

[4] It should be noted that although intentional nonlinear elements may improve the system performance under certain specified operating conditions, they will, in general, degrade system performance under other operating conditions.

我们应该注意到，尽管在某些工作条件下人为加入的非线性组件可以改进系统的性能，但是，总的来说，在其他工作条件下，它们将降低系统的性能。

句中 It 是形式主语，而 that although…是实际主语从句，in general 是一个插入语。在

翻译这句话时，不能按照原句的语法结构翻译成：“尽管在某些工作条件下人为加入的非线性组件可以改进系统的性能应该被注意到，……。”如果这样，就不符合汉语的习惯，读起来十分别扭。而是应该在尊重原文的基础上，按照汉语的习惯适当改写。

[5] The describing-function method provides stability information for a system of any order, but it will not give exact information as to the time-response characteristics.

描述函数法可以为任何阶次的系统提供稳定性信息，但是，它不能提供时间响应特性的确切信息。

本句为并列句，but 表示语气转折。句中 as to…介词短语修饰 information。

Translating Skills　被动语态的翻译

由于英汉两种语言的差别和行文的需要，注重形合的英语中，大量的及物动词需使用被动形式，还有相当多的具有及物动词功能的短语也使用被动语态，注重意合的汉语则少用被动形式。而科技英语中因强调信息传递的客观、科学性，所以被动语态的使用尤其广泛。因此在英汉互译的过程中（这里着重讲述英语译成汉语）应注意被动语态与主动语态的恰当转化，以符合译入语的习惯。

1. 翻译成有被动标记的被动句

所谓有被动标记，即带有助词“被”、“受”、“让”、“遭”、“给”、“叫”、“靠着”、“加以”、“挨”、“予以”、“得到”、“将”、“把”、“使”、“由”、“请”、“被……所”和“为……所”等为标记。如：

(1) The whole process **by** which machines **can be used** to work for us **has been called** automation.

利用机器为我们工作的整个过程**被**称为自动化。

(2) They **were attacked** in the storm last night.

他们昨晚**遭到**暴雨**袭击**。

(3) The volume could hardly **be heard** clearly if it was not amplified.

声音若不**进行放大**就很难听清。

(4) Such a measure **is usually provided by** a criterion of optimization, or performance index.

这种测量值通常**根据**优化原则或性能指标**来确定**。

(5) To a considerable degree, use of optimization theory in system design **has been much hampered by** the conflict between analytic feasibility and practical utility in the selection of the performance index.

在系统设计时，优化理论应用于选择性能指标，在很大程度上要**受到**分析的可能性和实际应用上的矛盾的**限制**。

2. 翻译成无被动标记的被动句或无主句

这类汉语句子在形式上是主动句，但其实主语是谓语动词的动作承受者，不是执行者，

是暗含的被动句；英语中有些由动词+名词+介词构成的短语动词相当于及物动词，可以有被动语态。但整个短语动词要作为整体看待，不能拆开，在意义上也是一个整体。翻译成汉语时，把主语和宾语合译，变为无主句如：

(6) The speed error **is corrected** at the maximum permissible armature current until the speed error becomes small and the current limiter comes out of saturation.

在最大允许电枢电流下**纠正**速度偏差，直到速度偏差减小且限流装置退出饱和状态。

(7) Adjustable-speed drives **are** also **being introduced** in new application areas.

在一些新的应用领域中也**引入了**调速传动系统。

(8) Only objects **struck by** the light are visible.

光**照射**到的物体是可见的。

(9) A new robot **was developed** last year.

去年**研制**出了新型的机器人。

(10) Except for special cases, the problem may be so complicated for analytic solution that a computational solution **must be obtained.**

除特殊情况外，最优控制问题的解析解都很复杂，因此必须**求**其数值解。

(11) **Care should be taken** not to damage the instruments.

注意不要损坏仪器。

(12) Attention **has been paid** to this phenomenon.

已经**注意**这种现象了。

3. 翻译成主动句

当英语的被动句不太强调被动意义时，往往根据汉语的习惯译成主动句；当动作的执行者由介词 by 引出时，多把 by 的宾语翻译成汉语的主语，原来英语句中的主语即动作的承受者译成汉语的宾语；在有些固定结构中，或者没有交代动作的执行者但交际的双方都明白执行者是谁，翻译时可以加上主语“人们”、“我们”“大家”、“有人”等，也可以不加；当英语中的一些被动句后跟介词短语作地点状语、方式状语等时，常把介词宾语译成汉语的主语，而英语句子中的主语译成汉语的宾语。

(13) Computers **are provided with** the capability of handling numerous data quickly.

计算机**具备了**迅速处理大量数据的能力。

(14) He **was given** the Nobel Prize this year.

今年他**得了**诺贝尔奖。

(15) Only several enterprises **would be permitted** to make five mascots for the 2008 Olympics.

只有几家企业**获准**生产 2008 奥运吉祥物。

(16) Light and heat **can be given** to us by the sun.

太阳**供给**我们光和热。

(17) **It is said that** two guests were stolen in the hotel.

据说这家宾馆的两个客人失窃了。

(18) **It is thought that** he is the king of rock and roll.

人们认为它是摇滚乐之王。

(19) A flying object **is reported to have been seen** over some southern province.

有人报道说南方某一省看到了不明飞行物。

(20) The extension plan for the university **is being discussed** at the meeting.

会议正在**讨论**该大学的扩建方案。

(21) Recently, the new kind of vaccine against avian flu has **been developed** in our country.

最近我国**研制出来**了一种新的预防禽流感的疫苗。

有时需根据句意引申翻译成主动句。如：

(22) The girl **can’t be taught**.

这孩子**没有能力学**。

4. 翻译成“是”句

有些描述事物的过程、性质和状态的英语被动句，翻译成汉语时往往加上“是……的”结构，变为汉语的“是”句。

(23) Iron **is extracted from** the ore by means of the blast furnace.

铁**是**用高炉从铁矿中提炼出来**的**。

(24) 20 Volts **were read from** the voltmeter.

电压表的读数**是** 20 伏。

(25) These reports **should be fully utilized by** us when studying a project.

这些报告**是**我们在研究项目时应该充分利用**的**。

(26) Everything **is built up** of atoms.

万物**是**由原子构成的。

5. 翻译成因果句

有些英语的被动句主语、by 引出的宾语和谓语动词之间有逻辑上的因果关系，这时可以加上表示因果关系的词“因为”、“因”、“是因为”等。如：

(27) The throat **is affected by** a cold.

喉咙**因**患风寒而痛。

(28) The meeting **was rained out.**

会议**因**雨停开了。

(29) His life **was cut** short by HIV.

他**因**患艾滋病而早亡。

Exercises

1. Translate the following into Chinese.

(1) If all the coefficients of a linear differential equation that describes a system are constants, the system is a Linear Time Invariant (LTI) system.

(2) The phase plane plot is a plot of y versus x. At each point (x,y) , dy/dx is the slope of the trajectory through that point.

(3) The output of the nonlinear element is a periodical signal of the same frequency as input.

(4) It is well known that one of the greatest scientists so far is Einstein.

(5) For simplification only one ground wire and one power conductor are shown.

(6) You can ask your supervisor to consider buying high-capacity laptops the next time PCs are purchased.

2. Translate the following into English.

(1) 相平面法和描述函数法是分析非线性系统的两种常用方法。

(2) 复杂的非线性控制器常常用于最优控制系统中。

(3) 传递函数和拉氏变换是线性系统中常用的分析和设计工具，不适用于包含非线性元件的非线性系统。

(4) NC 技术取得了迅速发展，它几乎应用于制造业的每一个领域。

(5) 一个陌生人给他提供了食物和住所。

(6) 手工编好的程序有时可从机床键盘送入控制器，这叫作手动数据输入。

Reading Material　An Introduction to Computer Simulation

Computers have long been used to create numerical and logical models of real-world systems, which we call simulation. Indeed, a large part of the motivation for developing the first computers in the 1930s and 1940s was to be able to perform calculations to simulate and analyze physical systems, such as electrical circuits and the flight of missiles. Since then, computer simulation has become an indispensable tool of scientists, engineers, economists, and other people who work with, and desire to understand, the behavior of complex systems.

Why do you build and use computer simulation models? There are many reasons, the following are among the most common.

In many cases, testing a real-world system can be prohibitively expensive or outright impossible. Seeing how an automobile collapses when it hits a barrier is an example of an expensive exercise to conduct in reality. But by crashing simulated cars into simulated walls on a workstation, automotive safety engineers can quickly evaluate potential designs and reduce the number of real cars that must be instrumented and sacrificed at the test track.

An example of an impossible-to-realize experiment would be estimating the environmental damage brought by an asteroid colliding with the earth. At present, we lack the ability to conduct this experiment in actuality. But on a computer, we can safely slam simulated asteroids of all sizes and shapes into various parts of a simulated earth all day long without having to worry about triggering real-world mass extinction.

Many systems are so complex that their correctness and behavior can be easily or confidently predicted, either analytically or through experience and intuition. An integrated circuit (IC) is one example of such a system. For the device to function properly, hundreds of thousands of individual circuits must operate exactly as planned. Isolating errors in the finished product can be difficult to find out. For this reason, software vendors have developed numerous specialized circuit-simulation tools to let the designer simulate a circuit performance on a computer under a variety of operating conditions and stimuli, and monitor the behavior of the circuit at any point. Without such tools, the development of even moderately complex ICs is vastly more difficult and expensive, and in many cases, nearly impossible.

Beyond allowing engineers to see if their designs work, computer simulations allow the rapid comparison of alternative designs. By comparing the performance of various permutations of a given design, an engineer can optimize the performance, cost, or other desirable attributes of the design, subject to the constraints within which it must function.

Finally, you can use computer simulations to obtain qualitative insights into how a system behaves. Even relatively simple systems can exhibit non-intuitive and genuinely surprising behaviors, which may not be apparent from their mathematical formulations. Computer modeling and simulation has greatly aided research into complex systems in such fields as ecology, aerography and astrophysics.

New Words and Phrases

1. simulation [ˌsimjuˈleiʃən]	n.	仿真，模拟
2. complex system		复杂系统
3. outright [ˈautˈrait]	adj.	直率的，彻底的，完全的
	adv.	直率地，痛快地，立刻地，全部地
4. indispensable [ˌindisˈpensəbl]	adj.	不可缺少的
5. motivation [ˌməutiˈveiʃən]	n.	动机
6. asteroid [ˈæstərɔid]	n.	小行星，流星
	adj.	星状的
7. slam [slæm]	v.	猛摔
8. trigger [ˈtrigə]	v.	触发，引起
9. extinction [iksˈtiŋkʃən]	n.	灭绝，消失
10. intuition [ˌintju(ː)ˈiʃən]	n.	直觉
11. moderately complex		适度复杂的
12. stimulus [ˈstimjuləs]	n.	(pl. stimuli) 刺激，促进因素
13. attribute [əˈtribju(ː)t]	n.	品质，属性
14. instrument [ˈinstrumənt]	n.	仪器，工具；
	v.	提供工具
15. prohibitively expensive		过于昂贵（使人无法承受）
16. permutation [ˌpəːmju(ː)ˈteiʃən]	n.	改变，交换，置换
17. qualitative insights		定性的观察
18. ecology [i(ː)ˈkɔlədʒi]	n.	生态学
19. aerography [ɛəˈrɔgrəfi]	n.	气象学
20. astrophysics [æstrəuˈfiziks]	n.	天体物理学

Lesson 10 Introductions to Phase-Plane Analysis

Consider a second-order system described by the following ordinary differential equation:

$$\ddot{x} + f(x, \dot{x}) = 0 \tag{10-1}$$

where $f(x, \dot{x})$ is either a linear or a nonlinear function of x and $\dot{x}$. The time solution of this system may be obtained in the form of a plot of $x(t)$. It can also be illustrated by plotting $\dot{x}(t)$ versus $x(t)$ using time t as a parameter. [1]

We take x and $\dot{x}$ as the coordinate axis of a plane, and each point in this plane represents values of both x and $\dot{x}$. As t varies, this point moves along a curve in the x - $\dot{x}$ plane, indicating the locus of the system states. [2] Such a curve is called a trajectory.

The geometrical representation of the system behavior in terms of trajectories is called a phase-plane representation of the system dynamics. Although the phase-plane diagram will give a clear picture of the trajectories for second-order systems, it is usually difficult to visualize or construct trajectories for systems of third order. [3] For systems of higher orders than third, it is impossible to visualize trajectories. However, the idea of the motion of a representative point in two-dimensional space can be conceptually extended to *n*-dimensional space.

We are going to explain the phase–plane method through the following example. The differential equations of the system are:

$$\frac{\mathrm{d}x_1}{\mathrm{d}t} = f_1(x_1, x_2) \tag{10-2}$$

$$\frac{\mathrm{d}x_2}{\mathrm{d}t} = f_2(x_1, x_2) \tag{10-3}$$

where $f_1(x_1, x_2)$ and $f_2(x_1, x_2)$ are either linear or nonlinear functions of the variables x_1 and x_2, respectively. Equations (10-2) and (10-3) are called autonomous equations. This means that the independent variable t appears only in the form of derivatives. Thus, in an autonomous system, neither the forces nor the constraints vary with time.

The plane with rectangular coordinates x_1 and x_2 is called phase-plane, or state-plane. As a matter of fact, the phase plane is a two-dimensional state space.

Usually, it is assumed that the system has the following simpler form of differential equations:

$$\frac{\mathrm{d}x_1}{\mathrm{d}t} = x_2 \tag{10-4}$$

$$\frac{\mathrm{d}x_2}{\mathrm{d}t} = f(x_1, x_2) \tag{10-5}$$

Here we define $x_1 = x$, then $x_2 = \dot{x}$. The most common phase plane is the x - $\dot{x}$ plane. In this lesson, unless otherwise stated, we assume the phase plane to be the x - $\dot{x}$ plane.

The phase-plane analysis of systems of equations (10-2) and (10-3) yields a bird's eye view of the solutions for any possible initial conditions. In the field of control systems, the phase-plane method is particularly well suited to the analysis and synthesis of second-order systems when they are subjected to initial conditions and/or aperiodic inputs, such as step inputs, ramp inputs, and pulse inputs.[4]

From the fundamental theorem on the uniqueness of the solution of simultaneous differential equations, we know that the solution of equations (10-2) and (10-3) with a given initial condition is unique, provided that $f_1(x_1, x_2)$ and $f_2(x_1, x_2)$ in equations (10-2) and (10-3) are analytic. (A function is analytic at a given point if it is possible to obtain a Taylor series expansion of the function about the given point) .[4] This uniqueness result does not apply to the points where simultaneously $f_1(x_1, x_2) = 0$ and $f_2(x_1, x_2) = 0$. Such points are called singular points. Usually singular points are equilibrium points. Any other point in the phase plane is called an ordinary point.

If there are no other equilibrium points in the neighborhood of a given equilibrium point, then this equilibrium point is called an isolated one. Although many practical systems involve only isolated equilibrium points, there are some cases where it is not true. For example, for the system

$$\ddot{x}(t) + \dot{x}(t) = 0 \tag{10-6}$$

all points on the x axis are equilibrium points and, therefore, the equilibrium points are not isolated.

Obtaining first-order differential equations for second-order systems

Elimination of the independent variable t from equations (10-2) and (10-3) gives

$$\mathrm{d}x_2 / \mathrm{d}x_1 = f_2(x_1, x_2) / f_1(x_1, x_2) \tag{10-7}$$

Equation (10-7) is a first-order differential equation relating x_1 to x_2 , and, in fact, this equation gives the slope of the tangent to the trajectory passing through point (x_1 , x_2)。[5]

The state of the system given by equations (10-2) and (10-3) [or equation (10-7)] can be determined at any time t by the values of x_1 and x_2 .

The solution to equation (10-7) may be written

$$x_2 = \phi(x_1) \tag{10-8}$$

Equation (10-8) represents a curve in the phase plane and indicates a motion of a representative point on the curve. The solution curve, or trajectory, which is a plot of x_2 as a function of x_1 , is an integral curve of the system represented by equation (10-7) . The trajectory does not show time information explicitly. If needed, however, the trajectory can be graduated in time units.[6]

Phase-plane portraits

A family of trajectories is called a phase-plane portrait. The initial condition determines the initial location of a representative point on the trajectory. As time increases, the representative point moves along the trajectory. The phase-plane representation of an autonomous system depicts the totality of all possible states of the system, and thus the nature of the response of the system is shown directly in the phase-plane portrait. Since there is one and only one trajectory passing through any given ordinary point in the phase plane, the trajectories generated by all possible initial conditions do not cross each other, except at singular points. At singular points, dx_2/dx_1 is indeterminate since it is of the form zero over zero. An infinity number of trajectories may approach or leave a singular point.

For a system having a double-valued nonlinearity, such as hysteresis, the system is no longer analytical. In such a case, however, it may be possible to divide the region into a few sub-regions, within which the system is analytic so that the phase-plane method may be applied. Then the complete solution may be obtained by connecting piecewise analytic solutions. It should be noted that when the system response is defined by two or more second-order differential equations, trajectories might cross each other.

If a representative point is in the upper half of the x - $\dot{x}$ plane, the point moves to the right on a trajectory as time increases since a positive velocity ($\dot{x} > 0$) corresponds to an increase in the value of x with time. Similarly, if a representative point is in the lower half of the x - $\dot{x}$ plane, then the point moves to the left on a trajectory as time increases since a negative velocity ($\dot{x} < 0$) corresponds to a decrease in x with time. Thus, motion along a trajectory in the x - $\dot{x}$ plane is in the clockwise direction. When the trajectory crosses x-axis, the velocity $\dot{x}$ is zero. Therefore, the trajectory will cross the x-axis perpendicularly.

New Words and Phrases

1. illustrate [ˈiləstreit]	v.	图解，阐明
2. coordinate [kəuˈɔːdinit]	n.	同等物，坐标(复数)
	adj.	同等的，并列的
	vt.	调整，整理
3. versus [ˈvəːsəs]	prep.	对(指诉讼，比赛等中)，与……相对，反对，与……相反
4. trajectory [trəˈdʒekətəri]	n.	轨道，轨迹
5. dynamics [daiˈnæmiks]	n.	动力学，动态(性能)
6. visualize [ˈvizjuəlaiz]	v.	可视化，形象化，显示
7. a bird's eye view of		(某事件)的概况，鸟瞰
8. synthesis [ˈsinθisis]	n.	综合
9. derivative [diˈrivətiv]	n.	导数，微商
10. analytical [ˌænəˈlitikəl]	adj.	解析的
11. infinity [inˈfiniti]	n.	无限，无穷大
12. simultaneous differential equations		联立微分方程组
13. autonomous [ɔːˈtɔnəməs]	adj.	自治的，有自治权的，独立的，独立自主的

14. synthesize [ˈsinθisaiz]	vt.	综合，合成，人工合成，综合处理
15. rectangular [rekˈtæŋgjulə]	adj.	矩形的，成直角的，直角坐标的
16. equilibrium point		平衡点
17. singular point		奇异点，奇点
18. aperiodic [ˌeipiəriˈɔdik]	adj.	不定期的，[物]非周期的
19. step input		阶跃输入，步进输入
20. ramp input		斜坡输入
21. pulse input		脉冲输入
22. Taylor [ˈteilə]	n.	Brook Taylor，布鲁克·泰勒 1685—1731，英国数学家
23. Taylor series expansion		泰勒级数展开
24. equilibrium [ˌiːkwiˈlibriəm]	n.	平衡，平静，均衡，保持平衡的能力，沉着，安静
25. singular [ˈsiŋgjulə]	n.	单数
	adj.	单一的，非凡的，异常的，持异议的，单数的
26. elimination [iˌlimiˈneiʃ ən]	n.	排除，除去，消除，消灭
27. hysteresis [ˌhistəˈriːsis]	n.	滞后，磁滞现象
28. correspond [kɔrisˈpɔnd]	v.	符合，相应
29. tangent [ˈtændʒənt]	adj.	接触的，切线的，相切的，离题的
	n.	切线，[数]正切
30. explicitly [iksˈplisitli]	adv.	明白地，明确地
31. graduate [ˈgrædjueit]	n.	(大学)毕业生，研究生，量筒
	v.	(使)(大学)毕业，标以刻度，分等级
32. in the field of		在……方面，在……范围内
33. piecewise [ˈpiːswaiz]	adv.,adj.	分段(的)，片段(的)
34. perpendicular [ˌpəːpənˈdikjuləli]	adv.	垂直地，正交地，直立地

Notes

[1] The time solution of this system may be obtained in the form of a plot of $x(t)$. It can also be illustrated by plotting $\dot{x}(t)$ versus $x(t)$ using time t as a parameter.

该系统的时间解可以由 $x(t)$ 的曲线形式获得，也可以通过以 t 作为参数画出的 $\dot{x}(t)$ - $x(t)$ 曲线图来说明。

后面一句中的 It 是指前句中的 The time solution of this system，现在分词短语 using time t as a parameter 作条件状语。

[2] As t varies, this point moves along a curve in the x - $\dot{x}$ plane, indicating the locus of the system states.

随着 t 的变化，这一点沿着 x - $\dot{x}$ 平面中的一条曲线移动，表示系统状态的轨迹。

句中的现在分词短语 indicating…作状语，表示伴随情况。

[3] Although the phase-plane diagram will give a clear picture of the trajectories for

second-order systems, it is usually difficult to visualize or construct trajectories for systems of third order.

尽管相平面图可以清楚地给出二阶系统的轨迹图，但是对于三阶系统通常难以画出或构造轨迹。

句中的 it 为形式主语，动词不定式短语 to visualize…作主语。

[4] From the fundamental theorem on the uniqueness of the solution of simultaneous differential equations, we know that the solution of equations (10-2) and (10-3) with a given initial condition is unique, provided that $f_1(x_1, x_2)$ and $f_2(x_1, x_2)$ in equations (10-2) and (10-3) are analytic. (A function is analytic at a given point if it is possible to obtain a Taylor series expansion of the function about the given point)

从微分方程解的唯一性的基本理论我们知道，只要联立微分方程组(10-2) 和(10-3) 中的 $f_1(x_1, x_2)$ 和 $f_2(x_1, x_2)$ 解析，则具有某个初始条件的方程(10-2) 和(10-3) 的解是唯一的。(一个函数如果能在某个给定点作傅里叶级数展开，则该函数在该给定点解析)。

句中的介词短语 From the fundamental theorem…作状语，而 provided that…则是另外一个条件状语从句。

[5] Equation (10-7) is a first-order differential equation relating x_1 to x_2, and, in fact, this equation gives the slope of the tangent to the trajectory passing through point (x_1, x_2).

方程(10-7)是 x_2 关于 x_1 的一阶微分方程。而且，这个方程实际上给出了轨迹通过点(x_1, x_2) 的切线的斜率。

句中“differential equation relating x_1 to x_2”表示“x_2 关于 x_1 的一阶微分方程”。这是一个并列句，and 起连接作用。后半句中的 slope 是宾语，而介词短语 of the tangent…作定语，修饰 slope。

[6] The trajectory does not show time information explicitly. If needed, however, the trajectory can be graduated in time units.

该轨迹没有显示具体的时间信息。当然，如果需要，该轨迹也可以按照时间单位来标定。

句中的 however 是插入语，表示语气的转折，而 can be graduated in time units 表示“可以以时间为单位来标刻度”。

Translating Skills　否定句的译法

由于英汉两种语言习惯的不同，在表达否定概念时，分别使用各异的词汇、语法手段和语言逻辑，因而使英语的否定句变得复杂难于理解。在翻译的过程中，不管其形式是肯定或否定，都要认真分析，准确把握，从句子所表达的意义出发，找准否定的部分，然后进行翻译。翻译的技巧通常有：直接翻译成否定句；英语从正面表达汉语从反面表达；英语从反面表达汉语从正面表达。

1. 翻译成汉语的否定式

从意义上来说，英语的否定句分为全部否定、部分否定、半否定、双重否定和用一些

习惯用语或词缀表示的否定。从形式上来说，有否定谓语动词和系动词的；有否定句子其他成分的。这些否定概念都用一些不同词类的词来表示。当英语的否定式与汉语的否定式相一致时，常常直接翻译成汉语的否定句；当英语句子所表达的意义相当于汉语的否定意义时，也翻译成汉语的否定句。翻译时要根据上下文语境，理清思路，正确理解意义，译出符合常识、逻辑和汉语习惯的句子。如：

(1) I have **never** heard of the news. (当句中出现 never, no, none, nobody, nothing, no one, nowhere, neither… nor…，no means, in no way，hardly, scarcely, rarely, hardly… ever…, 等词或短语表示否定时，可直接翻译成否定式)

我**从来没有**听说过这个消息。

(2) **None** of the students are late. (同上)

没有一个学生迟到。

(3) I like **neither** of the two books. (同上)

这两本书我**都不**喜欢。

(4) On no account did I go there.

我**决不**去那里。

(5) The color does **not** go with that. (当否定词直接否定谓语动词时，可直接翻译成汉语的否定式)

这颜色和那颜色**不**相配。

(6) The seat is **not** engaged.(同上)

这个座位没人占。

(7) It was **hopeless** to ask you again. (英语中有些词加上表示否定意义的前缀或后缀时，可翻译成汉语的否定式。一些常见的否定前缀或后缀有“non-不，非，无”，“dis-否定，相反”，“counter-反对，相反”，“un-, im-, in-, il-不，无，非”，“anti-反对”，“under-过少，在……下面”，“countra-相对，相反”，“-proof 能防……”，“-free 免……”等)

再问你也是**无用。**

(8)It is **impossible** that he is a thief. (同上)

他**不可能**是小偷。

(9)**All** is **not** gold that glitters. (当 not 与 all, every, both, always 等词连用时，常翻译成否定句。)

闪光的东西**并不一定都**是金子。

(10) **Not every** person can do the job. (同上)

不是每一个人都能干这份工作。

(11) We have **not** heard from John **as well as** from Mary.(当 not 与 as well as 连用时，not 后面的词是否定意义，as well as 后面的词是肯定意义，汉译时要当心)

我们收到了玛丽的信，**但没**收到约翰的信。

(12) You did **not** read the poem distinctly **and** moderately.(当 not 和 and 连用，and 连接的两个并列成分在句中作表语状语或定语时，and 前的成分表肯定，后的成分表否定。)

这首诗你读得很清楚，**但**节奏快慢掌握得不好。

(13) If it were **not** enough acceleration, the earth satellite would **not** get into space.(该句是

双否定句，根据句子的语气可以译成否定句)

如果**没有**足够的加速度，地球卫星就**不能**进入太空。

2. 正反译

所谓正反译就是英语从正面表达汉语从反面表达。英语句子中有些词或短语从形式上看是肯定的，但所表达意义却是否定的，如 ignorant, absent, failure，keep… from…, fail, beyond，above，miss，free from，instead of，lack 等，可翻译成汉语的带“不”，“非”，“无”，“没有”，“未”，“否”等否定字眼的句子；有一些词不管从意义上或是形式上都表示肯定意义，但为了更符合汉语的习惯，可以适当转换语气，翻译成汉语时从反面表达，如 exceed，tie，deceptive，before，final 等；还有一些词不管从正面表达或从反面表达都行得通，如 exactly，keep，safely 等。

(14) We will **ill** afford the time and money.

我们**几乎无力**负担所有的时间和金钱。

(15) This problem is **above** me.

这个问题我**不懂**。

(16) Good lubrication keeps the bearing **from** being damaged.

润滑良好**使**轴承**不**受损坏。

(17) Japan is **the last** country to invent radar, but England.

发明雷达的国家**决不是**日本，而是英国。

(18) I will do it now **before** I forget it.

趁还没有忘记，我现在就来做这件事。

(19) The ship had a crew of 48, **exclusive** of officers.

船上有船员 48 人，**不包括**高级船员。

(20) During my **absence**, I asked my friend to take care of my baby.

我**不在**时，我请我的朋友帮着照顾我的孩子。

(21) The beautiful girl displayed a complete **lack of** courtesy.

这位漂亮的女孩表现得极端**无**礼。

(22) The two teams **tied**.

两队**不分胜负。**

(23) Appearances can be **deceptive.**

外表是**靠不住的。**

(24) When the demand **exceeds** the supply, we should produce more products.

当产品供**不应**求时，我们应该生产得更多。

(25) **Exactly!**

一点不错！

(26) We may **safely** say so.

我们这样做**万无一失**。

(27) If it worked once, **it can work twice.**

一次得手**，再次不愁**。

3. 反正译

有些英语句子从反面表达，翻译成汉语时从正面表达，即不带汉语的否定词“不，无，非”等。英语中的双重否定句在翻译成汉语的时候，常从正面表达。所谓双重否定句是指一个句子里有两个否定词或表示否定意义的词。有的英语句子在形式上是否定式，但意义却是肯定的，译成汉语时可从正面表达，如 not until 可译成“直到……才”。有的句子意义和形式上都是否定意义，但为了符合汉语的语气和习惯也从正面翻译。

(28) Gases **cannot** be quickly compressed **without** generating heat.
气体迅速压缩就**一定**会产生热量。

(29) He doesn’t do it for **nothing.**
他这样做**是有**道理的。

(30) There is **no** surgical patient I **can’t** treat competently.
无论什么样的外科病人，我**都**能诊治。

(31) We are **not unprepared** for the outcome of the conference.
对于会议的结果，我们**是有准备的**。

(32) Please **lose no time** in despatching our goods.
请**立即**为我们发货。

(33) They did **not** come back **until** eight o’clock.
他们**直到** 8 点**才**回来。

(34) Our visit **couldn’t** be **more** successful.
我们的访问**很**成功。

(35) The doubt was still **unsolved** after his repeated explanations.
尽管一再解释，疑团依然**存在**。

(36) Teachers, **with no exception,** are to attend the routine meeting on Tuesdays.
每周二下午，所有老师**统统都要**开例会。

Exercises

1. Translate the following into Chinese.

(1) The phase-plane method is a geometrical representation of the system dynamic behavior in terms of trajectories in the x - $\dot{x}$ plane.

(2) The equilibrium point is called an isolated ones if there are no other equilibrium points in its neighborhood.

(3) If a representative point is in the upper half of the x - $\dot{x}$ plane, the point moves to the right on a trajectory as time increases since a positive velocity ($\dot{x} > 0$) corresponds to an increase in the value of x with time.

(4) Left untreated, each person with active TB(结核病) disease will infect on average between 10 and 15 people every year.

(5) Not a college student but what studies English.

(6) It’s quite beyond me why she married such an old man.

2. Translate the following into English.

(1) 相平面图由 x - $\dot{x}$ 平面中的一簇曲线组成，它们表示二阶系统的状态(x 和 $\dot{x}$ 的值)随时间增加而变化的特性。

(2) 除奇点外，由所有可能的初始条件产生的轨迹互相不会交叉。在奇点上，$\mathrm{d}x_2 / \mathrm{d}x_1$ 具有 $0/0$ 形式，因而是不定的。可以有无数个轨迹进入和离开一个奇点。

(3) 如果一个点在 x - $\dot{x}$ 平面的下半平面，随着时间增加该点在轨迹上向左运动。

(4) 然而，德尔佩、霍克和林克莱特都认为这些角色十分丰富，应该继续挖掘。

(5) 他和他的哥哥一样聪明。

(6) 直到 1788 年才发现了产生电流的方法。

Reading Material　Mass-Spring-Damper System

The simplest model for many vibratory systems is the mass-spring-damper system shown schematically in Fig. 10.1. The mass-spring-damper system is an accurate representation of many actual structures or devices; examples include an accelerometer (a device for measuring acceleration) , a seismometer (a device for measuring the vibration of the earth) , and a vibration absorber (a mounting device that is used to absorb vibration of equipment) . Other systems, such as a machine tool or a compressor on a resilient mount, can be modeled as a mass-spring-damper system for simplified analysis. This system, while crude, demonstrates most of the phenomena associated with vibratory systems, and, as such, it is the fundamental building block for the study of vibration.

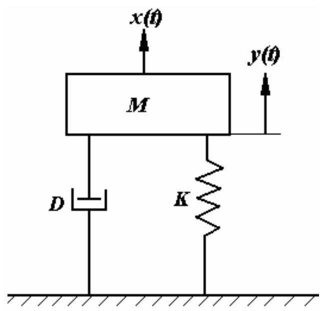


Fig. 10.1　Schematic diagram of Mass-spring-damper system

Physically, the mass M is supported by a spring with stiffness constant K and a damper with damping constant K . An external force $x(t)$ is applied to the mass and causes the mass to move upward or downward with displacement $y(t)$, measured with respect to an equilibrium value. (That is, $y(t)=0$ when no external force is applied.) When the mass is above its equilibrium value, $y(t)>0$, and when the mass is below its equilibrium value, $y(t)<0$. The movement of the mass is resisted by the spring (if the mass is moving downward, it compresses the spring, which then acts to push upward on the mass). The damper acts to dissipate energy by converting mechanical energy to thermal energy, which leaves the system in the form of heat. For example, a shock absorber in a car contains a damper.

The input/output differential equation for the mass-spring-damper system is given by

$$M\ddot{y}(t)+D\dot{y}(t)+Ky(t)=x(t) \tag{10-9}$$

Perform Laplace transform to equation (10-9) , and we get the transfer function of the system.

$$\frac{Y(s)}{X(s)}=\frac{1}{Ms^2+Ds+K} \tag{10-10}$$

By employing the software MATLAB/Simulink, we may create a simulation model of the system. And we may obtain the response plots to a step input, by setting M, K and D with different values.

New Words and Phrases

1. vibratory [ˈvaibrətəri]	adj.	振动的
2. damper [ˈdæmpə]	n.	阻尼器
3. damping constant		减幅常数，阻尼常数
4. stiffness [ˈstifnis]	n.	刚性
5. schematically [skiˈmætikəli]	adv.	图解地，图示地
6. accelerometer [ækˌseləˈrɔmitə]	n.	加速度计
7. seismometer [ˈsaismɔmitə]	n.	地震仪
8. phenomenon [fiˈnɔminən]	n.	(pl. phenomena)现象
9. dissipate [ˈdisipeit]	v.	消耗，耗散
10. machine tool		机床
11. compressor [kəmˈpresə]	n.	压缩机
12. resilient [riˈziliənt]	adj.	有回弹力的，弹回的
13. shock absorber		缓冲器，防震器，减震器，阻尼器

Lesson 11 Discrete-time Systems and the z-Transform Method

Discrete-time systems, or sampled-data system, are dynamic systems in which one or more variables can change only at discrete instants of time. These instants, which we shall denote by kT or $t_k(k=0,1,2,\ldots)$, may specify the time at which some physical measurement is performed or the time at which the memory of a digital computer is read out, etc. [1] The time interval between two discrete instants is taken to be sufficiently short so that the data for the time between these discrete instants can be approximated by simple interpolation.

Discrete-time systems differ from continuous-time ones in that the signals for a discrete-time system are in sample-data form.

Discrete-time systems arise in practice whenever the measurements necessary for control are obtained in an intermittent fashion, or a large scale controller or computer is time-shared by several plants so that a control signal is sent out to each plant only periodically or whenever a digital computer is used to perform computations necessary for control. [2] Many modern industrial control systems are discrete-time systems since they invariably include some elements whose inputs and/or outputs are in time. Sometimes, however, sampling operation, or discretization, may be entirely fictitious and introduced only to simplify the analysis of control system which actually contains only continuous elements. [3]

In this lesson, we shall be concerned with discrete-time systems which the signal representing the control efforts is piecewise constant and changes only at discrete points in time. Since there are several different types of sampling operation of practical importance, we shall list them as follows:

(1) Periodic (conventional) sampling: In this case, the sampling instants are equally spaced, or $t_k=kT$ ($k=1,2,3\ldots$)

(2) Multiple-order sampling: The pattern of the t_k is repeated periodically, or $t_{k+r}-t_k$=constant for all k.

(3) Multiple-rate sampling: In this case, two concurrent sampling operations occur at $t_k=pT_1$ and qT_2, where T_1,T_2 are constants and p, q are integers.

(4) Random sampling: In this case, the sampling instants are random, or t_k is a random variable.

Here we shall treat only the case which the sampling is periodic.

Quantization. The inclusion of digital computer in an otherwise analog system produces in digital form (usually as binary numbers) in part of the system. The system then takes the form of a mixed digital–analog combination. The introduction of a digital computer in a control system requires the use of digital-to-analog and analog-to-digital converters. The conversion of an analog signal to the corresponding digital signal (binary number) is an approximation because the analog signal can take an infinite number of values, whereas the variety of different numbers which can be formed by a finite set of digits is limited. This approximation process is called *quantization.*

The process of quantizing (converting a signal in analog form to digital form) may be fulfilled by means of some specific circuits. The range of input magnitudes is divided into a finite number of disjoint intervals h_i which are not necessarily equal. All magnitudes falling within each interval are equated to a single value within the interval. This single value is the digital approximation to the magnitudes of the analog input signal. Thus, if x is the analog input, the digital output is given by $y=Q(x)$ where Q is the quantizing function.

The function $x(t)$ is a discrete-time function. The operation of digital control systems involves quantization both in amplitude and in time. We shall next present the definitions of several terms.

Transducer. A transducer is a device which converts an input signal into an output signal of another form. (The output signal, in general, depends on the past history of the input).

Analog transducer. An analog transducer is a transducer in which the input and output signals are continuous functions of time. The magnitudes of these signals may be any value within the physical limitations of the system.

Sampled-data transducer. This is a transducer in which the input and output signals occur only at discrete instants of time (usually periodic) , but the magnitudes of the signal, as in the case of the analog transducer, are unquantized.

Digital transducer. A digital transducer is one in which the input and output signals occur only at discrete instants of time, and the signal magnitudes are quantized. i.e., they can assume only certain discrete levels.

Analog-to-digital transducer. This is a transducer in which the input signal is a continuous function of time and the output signal is a quantized signal which can assume only certain discrete levels. [4]

Digital-to-analog transducer. A digital-to-analog transducer is one in which the input signal is a quantized signal and the output signal is a smoothed continuous function of time.

Analog controllers and digital controllers. In considering the types of controllers which are used in industrial control system, we may divide them into the following three categories:

Analog controllers or computers: Analog controllers or computers represent the variables in the equations by continuous physical quantities. Analog controllers can be designed which will satisfactorily serve as nondecision making controllers.

Digital controllers or computers: These operate only on numbers. Decision-making is an important function in digital controllers, and they are currently being used for the solution of problems involving the optimal overall operation of industrial plants.

Analog-digital controllers or computers: These are often called hybrid controllers. They are combinations of analog controllers and digital controllers. Some of the high performance controllers are of this type.

Advantages of digital controllers over analog controllers. Some of the advantages of digital controllers over analog controllers may be summarized as follows:

(1) Digital controllers are capable of performing complex computations with constant accuracy at high speed. Digital computers can have almost any desired accuracy in computations at relatively little increase in cost. On the other hand, the cost of analog computers increases rapidly as the complexity of the computations increase if constant accuracy is to be maintained.

(2) Digital controllers are extremely versatile. By merely issuing a new program, one can completely change the operations being performed. This feature is particularly important if the control system is to receive operating information or instructions from some computing center, where economic analysis and optimization studies are being made.

Because of the inability of conventional techniques to adequately handle complex control problems, it has been customary to subdivide a process into smaller units and handle each of these as a separate control problem. Human operators are normally used to coordinate the operation of units. Recent advances in computer control systems have caused changes in this use of industrial process controls. Recent developments in large-scale computers and mathematical methods provide a basis for use of all available information in the control system. In conventional control, this part of the control loop is being done directly by humans.

Computer control of complex systems. Current trends in the control of large-scale systems are to consolidate the multiplicity of independently controlled units into single optimally controlled processes. In industrial process control system, it is, in general, not practical to operate for a very long time at steady state because certain changes in production requirements, raw materials, economic factors, and processing equipment and techniques, may occur. [5]Thus, the transient behavior of industrial processes must be taken into consideration. Since there are interactions among process variable, using only one process variable for each control agent is not suitable for really complete control. By use of computer control, it is possible to take into account all process variables together with economic factors, production requirements, equipment performance, etc., and to thereby accomplish optimal control of industrial processes.

Note that a system capable of controlling a process as completely as possible will have to solve complex equations. The more complete the control, the more important it is that the correct relations between operating variables be known and be used. The system must be capable of accepting instructions from such varied sources as computers and human operators and must also be capable of changing its control subsystem completely in a short time.

z-transform approach and state-space approach to the analysis of discrete-time systems. The analysis of discrete-time system may be carried out easily in either of two different approaches. One is the z-transform approach and the other is the state-space approach.

The z-transform approach has the same relationship to linear time-invariant discrete-time systems as the Laplace transform approach bears to liner time-invariant continuous-time systems.

This section presents only the z-transform approach to the analysis of linear time-invariant discrete-time system.

New Words and Phrases

1. discrete [dis'kriːt]	adj.	不连续的，离散的，分离的，分立的，松散的，个别的，专用的
2. z-transform		z 变换
3. denote [di'nəut]	vt.	指示，表示，代表
4. interpolate [in'təːpəuleit]	v.	窜改，添写进去，添写，插补
5. intermittent [ˌintə(ː)'mitənt]	adj.	间歇的，断断续续的
6. discretization [disˌkriːti'zeiʃən]	n.	[数]离散化
7. fictitious [fik'tiʃəs]	adj.	假想的，编造的，虚伪的，习惯上假定的，假装的，小说中的
8. piecewise [`piːswaiz]	adv.	[数]分段地，片段地
	adj.	分段的，片段的
9. concurrent [kən'kʌrənt]	n.	同时发生的事件
	adj.	并发的，协作的，一致的
10. binary ['bainəri]	adj.	二元的，两重的，二进制的
11. quantization [ˌkwɔntai'zeiʃən]		量化，量子化，取离散值，数字转换，变量分区法
12. disjoint [dis'dʒɔint]	v.	(使)脱节，(使)解体，(使)脱臼，拆开，肢解，使混乱
	adj.	不相交的，分离的
13. transducer [trænz'djuːsə]	n.	传感器，变频器，变换器，换能器，换流器
14. subdivide ['sʌbdi'vaid]	v.	再分，细分
15. trend [trend]	n.	倾向，趋势
	vi.	伸向，倾向，通向
16. consolidate [kən'sɔlideit]	vt.,vi.	使坚强，巩固，强化，统一，合并
17. multiplicity [mʌlti'plisiti]	n.	大数目，多种多样，繁多，多样性
18. interaction [ˌintər'ækʃən]	n.	交互作用，交感，互相作用，互相影响
19. magnitude ['mægnitjuːd]	n.	大小，数量，巨大，广大，量级，幅度
20. bear [bɛə]	n.	熊
	v.	负担，忍受，带给，具有，生育，支撑，支持
21. element ['elimənt]	n.	要素，元素，成分，元件，自然环境
22. category ['kætigəri]	n.	种类，类别，[逻]范畴
23. control agent		控制介质，调节体

24. variable [ˈvɛəriəbl]　n.　[数]变数，可变物，变量
adj.　可变的，不定的，易变的，[数]变量的
25. quantize [ˈkwɔntaiz]　v.　使量化

Notes

[1] These instants, which we shall denote by kT or $t_k(k=0,1,2,\ldots)$, may specify the time at which some physical measurement is performed or the time at which the memory of a digital computer is read out, etc.

这些瞬时值可以用 kT 或 t_k 表示，指完成测量的时间或者读取数字计算机内存的时间。

句中由第一个 which 引导的非限定性定语从句修饰 These instants，而 at which some physical measurement is performed 和 at which the memory of a digital computer is read out 为定语从句，分别修饰两个 the time。

[2] Discrete-time systems arise in practice whenever the measurements necessary for control are obtained in an intermittent fashion, or a large scale controller or computer is time-shared by several plants so that a control signal is sent out to each plant only periodically or whenever a digital computer is used to perform computations necessary for control.

在实际应用中，当控制所需要的测量以间断的方式进行时，或者当大型的控制器或计算机被多个控制对象所共享，导致传送到每一个控制对象去的控制信号仅为周期性信号时，或者在采用数字计算机去完成控制所必需的计算时，就会产生离散系统。

句中 whenever 引导的从句作时间状语，so that 引导结果状语从句。

[3] Sometimes, however, sampling operation, or discretization, may be entirely fictitious and introduced only to simplify the analysis of control system which actually contains only continuous elements.

当然，采样操作或离散化有时完全是假设，其引进目的仅仅是为了简化实际上只包含连续性元件的控制系统的分析。

句中 which 引导的定语从句修饰 control system。

[4] This is a transducer in which the input signal is a continuous function of time and the output signal is a quantized signal which can assume only certain discrete levels.

这一转换器的输入信号是时间的连续信号，而输出信号则为量化信号，而且只取特定的离散值。

句中 in which 引导的定语从句修饰 a transducer，从句 which 引导的定语从句修饰 a quantized signal。

[5] In industrial process control system, it is, in general, not practical to operate for a very long time at steady state because certain changes in production requirements, raw materials, economic factors, and processing equipment and techniques, may occur.

一般来说，由于产品需求、原材料、经济因素、加工设备和方法的变化，工业过程控制系统实际上并不能长时间工作于固定的状态。

句子为主系表结构，不定式结构 to operate…作主语。

Translating Skills　不定式和分词作状语的翻译

英语中动词有 3 种非限定形式：to 不定式、-ing 分词和-ed 分词。不定式有两种：带 to 的不定式和不带 to 的不定式，不定式有一般式进行式和完成式，也有被动语态，在句中可作主语、表语、宾语、定语和状语等；-ing 分词有完成体和被动语态，在句中可作定语、表语、主语、补足语、宾语补足语和状语等；-ed 分词在句中可作定语、主语、补足语、宾语补足语和状语等。这 3 种形式在科技英语中经常出现。下面分别介绍 3 种形式在句中作状语的情况和翻译方法，熟悉 3 种非限定形式，对科技翻译将大有裨益。

动词不定式作状语的翻译

不定式在句中作状语可以修饰动词表示目的、结果、原因、条件和伴随；可以与一些形容词或副词形成固定搭配。因此应注意不定式与句子、句子中动词和其修饰的形容词、副词的关系，恰当进行翻译。

1. 带 to 的不定式的翻译

(1) The engine is designed **to be maintained at low cost**. (表目的，置句末，增译汉语表目的的词语“**按……**”)

这种发动机是**按维护成本低的**原则设计的。

(2) The car has been designed **to run at 140 kilometers per hour**.(表目的, 置句末，增译汉语表目的的词语“**用于……”，**“**用来……**”)

这种汽车是设计**用于以每小时 140 千米的速度行驶的。**

(3) **To meet our production needs,** more and more electric power will be generated.(表目的, 置句首，增译汉语表目的的词语“**为了……**”)

为了满足生产的需要，将生产越来越多的电力。

(4) What have I said **to make you so excited?**(表结果，增译汉语表结果的词语“**使……”，**“**使得……**”,“**让……**”,“**会……**”)

我说了什么话**让你这样激动**？

(5) When the effect of inductance is **such as to cause an induced voltage** in the same circuit in which the changing current is flowing, the term self-induction is applied to the phenomenon. (表结果，增译汉语表结果的词语“**足以……**”)

当电感效应在变化的电流流过同一电路里**足以引起感应电压**时，我们就用“自感”这个词来描述这一现象。

(6) We grieved **to hear of the sad news.** (表原因，常置句首，不定式动作先发生，汉译时不定式提前)

听到那不幸的消息，我们非常悲痛。

(7) You couldn’t do that **to pass the exam.**(表条件，一般置句首，增加汉语表条件的词)

即使为了通过考试，你也不能那样做。

(8) The manager divided the task, Betty **to typewrite the letter** and Smith **to arrange the files**. (表伴随，常带有逻辑主语，可分译)

经理分工，让贝蒂**打信**，史密斯**整理文件**。

2. 不带 to 的不定式的翻译

(9) Don't let **slip such a good film**. (动词与不定式合译)
不要**错过这么好的电影**。

(10) He will go **see his grandmother.** (go, run, come 后可省略不定式 to, 表命令、建议、请求、意愿，可直译)
他要去**看望祖母**。

3. 一些固定搭配的翻译

(11) The current is **too** small to measure. (too…to…结构中的不定式作结果状语，可适当加词直译)
这电流小得**难以测量**。

(12) I am very lucky **to co-operate with you in the project.**(不定式常跟在一些形容词后面，说明形容词所表示意义产生的原因，例如在 happy, ready, glad 等后面)
能在此项目中与您合作，我很荣幸。

(13) An equilibrium state x_e is said **to be unstable** if for some real number ε＞0 and real number δ＞0, no matter how small, there is always a state x_0 in $S(\delta)$ such that the trajectory starting at this state leaves $S(\varepsilon)$.(有些谓语动词，当主语不需说出或大家都明了时，经常用作被动语态，其后跟动词不定式的一般式或完成式，翻译时可把动词和不定式合译，或适当加词，灵活翻译，以符合汉语习惯。这类词有 say，report，respect，think，feel，know 等)。

如果对于某个实数ε＞0 和实数δ＞0，不管有多么小，在 $S(\delta)$ 内总存在着一个状态 x_0，使得由这一状态出发的轨迹离开 $S(\varepsilon)$，那么平衡状态 x_e 就**认为是不稳定的**。

(14) A further factor must now be introduced — the air is likely **to be loaded with water vapour.** (be likely to…译成“很可能”，后面的动词不定式直译)
现在必须考虑另一个因素，即这样的空气很可能**带有水蒸气。**

分词作状语的翻译

1.-ing 分词作状语的翻译

-ing 分词也叫现在分词，包括单词和短语。其位置灵活，根据表达的需要和句内的逻辑可前、可后、可中。当与句中主语没有逻辑上的主谓关系时，可有自己的逻辑主语。在句中作状语时，说明句子的动词或修饰整个句子，表示动作发生的时间、条件、原因、结果、让步、伴随等，翻译时根据动作发生的先后，与句子的关系和汉语的表达特点，适当的增加一些具有暗含意义的词，使衔接更加紧密、语义流畅，符合汉语习惯。如：

(15) **Flowing through a circuit,** the current will lose part of its energy. (作时间状语，常置句首，增加汉语中表示动作同时发生的词，像“……时”，“当……时候”等)
当电流流过电路时，要损耗掉一部分能量。

(16) **Knowing current and resistance,** we can find out voltage.(表时间的先后，适当增加汉语中表时间的词进行翻译)
知道了电流和电阻，我们就能求出电压。

(17) This alloy, **being capable of withstanding strong stresses and high temperatures,** is suitable for making the skin of an ultrasonic plane.(表原因，置句中，可以增加汉语中表原因的词翻译)

这种合金**由于能经受强应力和耐高温**，所以适用于制造超音速飞机的外壳。

(18) That is, the resulting control may be linear, nonlinear, stationary or time-varying, **depending on the form of the performance index.**(作伴随状语，表示与句子的动词同时发生，翻译时可增加 depending on 的逻辑主语，分译成汉语的一个句子。)

也就是说，所得到的控制可能是线性的、非线性的、定常的或者时变的，**而这些都取决于性能指标的形式。**

(19) **Strictly speaking**, we should realize that a mathematically obtained optimal control system gives, in most practical situations, the ultimate performance limitation under the given performance index…(插入成分，说明更加准确、严格，可分译成汉语的句子。)

严格地说，我们应认识到，在大多数实际应用中，用数学工具建立的最优控制系统，确定了在给定性能指标下的最终性能极限，……

(20) **Having been repaired several times**, the escalator does not work yet .(作让步状语，适当增加汉语表转折关系的词，像“虽然 A 但是 B”，“尽管 A 可是 B”等。)

电梯虽然已经修了好几次，但还是不能用。

(21) **Heating semi-conductors**, we can increase their conductivity. (在英语中作条件状语，在汉语中表假设关系，翻译时可适当增加汉语表假设关系的词，如“如果 A 就 B”，“假如 A 就 B”。)

如果加热半导体，我们**就**能提高它的电导率。

(22) The guard neglected his duties, **thus giving the thief a chance to steal a PC**.(作结果状语，翻译时可适当增加汉语表结果关系的词，如“结果”、“所以”、“因此”、“以至”等。)

门卫玩忽职守**，结果给小偷机会偷走了一台手提电脑。**

2. -ed 分词作状语的翻译

-ed 分词也叫过去分词，包括单词和短语。和现在分词一样，过去分词位置灵活。当位于句首时，句子的主语是分词的逻辑主语，这样可以避免引起歧义。翻译时认真分析，把握与句子的关系，适当增译，以符合汉语的习惯和句内逻辑。限于篇幅仅举几例。

(23) **United** we stand, **divided** we fall.(分词相当于条件状语从句，灵活增译表示条件的词。)

团结就是胜利，**分裂**必然失败。

(24) **Wounded,** the fireman continued to save the persons in the heavy fire. (分词表示让步含义，可增译“虽然”。)

虽然受伤，这位消防战士仍继续从大火中救人。

Exercises

1. Translate the following into Chinese.

(1) A radar screen is not unlike a television screen.

(2) The engine did not stop because the fuel was finished.

(3) In a thermal power plant, all the chemical energy of the fuel is not converted into energy.

(4) The analysis of three-phase circuits is little more difficult than that of single-phase circuit.

(5) Though computers are capable of learning from their mistakes and improving on their performance, they need detailed instructions from human beings in order to be able to operate.

(6) He made a long speech only to show his ignorance of automation.

(7) To monitor airborne particles, it is necessary to determine the chemical compositions of the various particles in the atmosphere.

2. Translate the following into English.

(1) 将传感器安装在传送装置上，可以检测传送装置实际上是否运动。

(2) 步进电机或控制器是获得精确位移最廉价的方法之一，但步进电机只适合接小负载。

(3) 为了使控制器能感觉到负载对系统的影响，接上负载后必须调节电动机。

(4) CNC 是使用特殊的 G 编码语言的多轴伺服系统。

(5) 热力发动机使用热能来做功。

(6) 尽管计算机有很多优点，但不能代替人。

(7) 基于这个原理，围绕地球等距离的位置上放置 3 颗卫星，就可建立一个全球的通信系统。

Reading Material　Motion Control

Motion control is using power to control the movement of a mechanical system. Most motion control is now performed using electric motors. Motors can be AC or DC, rotary or linear. Motion control can be as simple as applying power to the motor to use complex motion controllers for multi-axis contouring. Most of the motion control that we see falls into one of several categories:

(1) On/off control – quick and easy to implement;

(2) Steppers – small and inexpensive, good positioning for small loads;

(3) Inverters/Variable speed drives – for controlling larger loads;

(4) Servos – expensive, very good positioning, fast acceleration;

(5) Multi-axis, 2D or 3D control, including CNC and robotics.

There are typically three uses for motion control: positioning, speed, and torque control. Simple on/off control is the easiest type of motion control. For electric motors you have some sort of relay (starter) that simply applies power to the motor. Note you must also have fuses or circuit breakers, overload protection, and other safety mechanisms. We typically install some sort of feedback to indicate that the motor is actually running. For example a sensor will be placed on a conveyor to sense motion and provide confirmation to the system that the conveyor is in fact moving.

Feedback in automation systems is always a good idea. For example, supposing you have a machine dumping 20 parts per minute onto a moving conveyor. If the conveyor motor would fail then you have 20 parts per minute being dumped on top of each other (onto the floor, etc.).

Stepper motors are small motors where the magnetic field is rotated in small steps in order to make the motor rotate. A stepper motor usually requires a controller and a drive. The controller reads commands such as Acceleration 20 revolutions per second squared, Velocity 10 revolutions per second, Distance 2.3 inches, GO, and automatically generates the move profile that ramps the speed up to 10 RPS at an acceleration of 20 RPSS, maintains the 10 RPS speed and then decelerates the motor. Stepper motors and controllers are one of the least expensive ways to get accurate positioning but stepper motors only handle small loads. Contrary to what some people tell you, you can have encoders on stepping motors to reduce the effects of motor slip.

Low-end inverters are becoming so inexpensive that it is starting to justify using them for even simple on/off control. Another advantage of using inverters/variable speed drives is the feedback that you get. The drive will tell you the voltage, current, and other data about the application. So not only are you getting control but also monitoring capabilities as well.

Servomotors have more torque and capabilities than stepping motors but also cost about twice as much as stepping motors. Years ago, Servomotors were difficult to work with because you had to tune the motors and controllers. Most servo controllers now automatically tune the motors and their controller. It is important to tune motors after the load is attached so that the controller can see the effects of the load on the system. Servomotors are known as very accurate, fast, high torque, precise control.

CNC (Computer Numerically Control) is a multi-axes servo system which use a special G code language. The G code helps to make all controllers run the same program, although it usually is not that simple. Mechanical designers, with practice, can generate parts in AutoCAD, or similar software, run a program that generates G code, download it to the CNC controller, load metal stock into the machine, press the start button, and the machine will make the part.

Motion technology has made the most advancement due to solid state devices and communications. Today you can get inexpensive electronic controllers to do simplistic control, monitoring, and protection up to complex CNC and robotics controllers. Communications networks, such as Profibus, and more recently Ethernet, allow motion control to be tightly integrated with controllers and SCADA systems. Even with all the technological advances, designers and users of motion control still need to take a little extra time to first stop and consider the possible consequences before putting that system in motion.

New Words and Phrases

1. contour [ˈkɔntuə]	n.	轮廓，等高线
	adj.	与轮廓相合的，用等高线表示的
	vt.	画轮廓

2. inverter [in'vəːtə]	n.	换流器，变频器，逆变器，变换器，反相器，“非”门，转换开关
3. multi-axis		多轴
4. torque [tɔːk]	n.	扭矩，转矩，力矩，扭转力，变曲力
	vt.	使……旋转，扭转
5. circuit breaker		断路器，断路开关
6. conveyor [kʌn'veiə(r)]	n.	传送者，传播者，传送装置，传送带，输送机
7. dump [dʌmp]	vt.	倾倒(垃圾)，倾卸，转储，转出，摆脱，扔弃
	n.	堆存处
8. revolution [ˌrevə'luːʃən]	n.	革命，变革，旋转，转数，循环
9. stepper motor		步进电机
10. profile ['prəufail]	n.	剖面，外形，轮廓，侧面像，简介
	vt.	画……的轮廓，写……的传略
11. ramp [ræmp]	n.	斜坡，坡道，敲诈
	vi.	暴跳，乱撞，敲诈，蔓延
	vt.	使有斜面，敲诈

Lesson 12 State-space Analysis of Control Systems

From the previous discussion we know that the root-locus approach and the frequency-response approach are quite useful for dealing with single-input-single-output systems. For example, by means of open-loop frequency-response test, we can predict the dynamic behavior of the closed-loop system. If necessary, the dynamic behavior of a control system may be improved by inserting a simple lead or lag compensator. The techniques of conventional control theory are conceptually simple and require only a reasonable amount of computation.

In conventional theory, only the input, output and error signals are considered important. The analysis and design of control systems are carried out using transfer functions, together with a variety of graphical techniques such as root-locus plots, Nyquist plots and Bode diagrams. The unique characteristic of conventional control theory is that it is based on the input-output relation of the system, or the transfer function.

The main disadvantage of conventional control theory is that it is applicable only to single input and single output (SISO), linear time-invariant (LTI) systems. It is not suitable to deal with multiple-input multiple-output (MIMO) systems. And conventional techniques (root-locus and frequency-response methods, etc.) do not apply to the design of optimal and adaptive control systems, which are mostly time-varying and/or nonlinear. [1]

The modern engineering systems are becoming more complex, due mainly to the requirements of complex tasks and good accuracy. Complex systems may have multiple inputs and multiple outputs and may be time-varying. Because of the necessity of meeting increasingly stringent requirements on the performance of control systems, the increase in system complexity, and easy access to large-scale computers, modern control theory, which is a new approach to the analysis and design of complex control systems, has been developed since around 1960. [2] This new approach is based on the concept of state. The concept of state by itself is not new since it has been in existence for a long time in the field of classical dynamics and other fields. (In fact, the phase-plane, discussed in lesson 10, is a two-dimensional state-space.)

Modern control theory is contrasted with conventional control theory in that the former is applicable to MIMO systems, which may be linear or nonlinear, time-invariant or time-varying, while the latter is applicable only to linear time-invariant SISO systems. [3] Also, modern control theory is essentially a time-domain approach, while conventional control theory is a complex frequency-domain approach.

System design in classical control theory is based on trial-and-error procedures, which will not yield optimal control systems. [4] System design in modern control theory, on the other hand, enables the engineer to design optimal control systems with respect to given performance indexes. In addition, design in modern control theory can be carried out for a class of inputs, instead of a specific input function, such as the impulse function, step function, or sinusoidal function. Also, modern control theory enables the engineer to include initial conditions in the design.

Before we proceed further, we must define a few terms such as: state, state variable, state vector, and state space.

State. The state of a dynamic system is the smallest set of variables(called state variable) such that the knowledge of these variables at $t=t_0$, together with the input for $t\geqslant t_0$, completely determines the behavior of the system for any time $t\geqslant t_0$.

Thus, the state of a dynamic system at time t is uniquely determined by the state at time t_0 and the input for $t\geqslant t_0$, and it is independent of the state and input before t_0. Note that, in dealing with linear time-invariant systems, we usually choose the reference time t_0 to be zero.

State variables. The state variables of a dynamic system are the smallest set of variables that determine the state of the dynamic system. If at least n variables $x_1(t), x_2(t),\ldots, x_n(t)$ are needed to completely describe the behavior of a dynamic system (such that once the input is given for $t\geqslant t_0$ and the initial state at $t=t_0$ is specified, the future state of the system is completely determined) , then such n variables $x_1(t), x_2(t),\ldots, x_n(t)$ are a set of state variables. Note that the state variables need not be physically measurable quantities. Practically, however, it is convenient to choose easily measurable quantities for the state variables because optimal control laws will require the feedback of all state variables with suitable weighting.

State vector. If n state variables are needed to completely describe the behavior of a given system, then these n state variables can be considered to be the n components of a vector $X(t)$. Such a vector is called a state vector. A state vector is thus a vector which determines uniquely the system state $X(t)$ for any $t\geqslant t_0$, once the input $u(t)$ for $t\geqslant t_0$, is specified.

State space. The n-dimensional space whose coordinate axes consist of the $x_1(t)$ axis, $x_2(t)$ axis,…, $x_n(t)$ axis is called a state space. Any state of the system can be represented by a point in the state space.

A modern control system may have many inputs and many outputs, and these may be interrelated in a complicated manner. To analyze such a system, it is essential to reduce the complexity of mathematical expressions, as well as to resort to computers for most of the tedious computations necessary in the analysis. The state-space approach to system analysis is best suited for this viewpoint.

While conventional control theory is based on the input-output relationship, or transfer function, modern control theory is based on the description of system equations in terms of n first-order differential equation, which may be combined into a first-order vector-matrix differential equations. [5] The use of vector-matrix notation greatly simplifies the mathematical representation of systems. The increase in the number of state variables, the number of inputs, or the number of outputs does not increase the complexity of the equations. In fact, the analysis of complicated MIMO systems can be carried out by the procedures that are only slightly more complicated than those required for the analysis of systems of first-order scalar differential equations.

From the computational viewpoint, the state-space methods are particularly suited for digital-computer computations because of their time-domain approach. This relieves the engineers from the burden of tedious computations and enables them to devote their efforts solely to the analytical aspects of the problem. This is one of the advantages of the state-space method.

Finally, it is important to note that it is not necessary that state variables represent physical quantities of the system. Variables that do not represent physical quantities, and those which are neither measurable nor observable, may be chosen as state variables. Such freedom in choosing state variables is another advantage of the state-space method.

New Words and Phrases

1. lead or lag compensator		超前或滞后校正装置
2. applicable [ˈæplikəbl]	adj.	适用的，可应用的
3. latter [ˈlætə]	adj.	后面的，(两者中)后者的，较后的，近来的
4. easy of access		易于接近
5. with respect to		关于，至于
6. adaptive [əˈdæptiv]	adj.	适应的，自适应的
	vt.	使适应；使适合
7. sinusoidal [ˌsainəˈsɔidəl]	adj.	正弦的，正弦曲线的
8. vector [ˈvektə]	n.	[数]向量，矢量，带菌者
	vt.	无线电导引
9. weighting [ˈweitiŋ]	n.	衡量，评价，加权，加重
10. interrelate [ˌintə(ː)riˈleit]	vt.	(使)相互关联，互相联系
11. tedious [ˈtiːdiəs]	adj.	单调乏味的，沉闷的，冗长乏味的
12. resort [riˈzɔːt]	vi.	(与 to 连用)求助，诉诸，采取，常去
	n.	凭借，手段，常去之地，胜地
13. notation [nəuˈteiʃən]	n.	记数法，表示法，符号，记号
14. complicated [ˈkɔmplikeitid]	adj.	复杂的，难解的
15. matrix [ˈmeitriks]	n.	矩阵，母体，发源地
		(印)字模，纸型
16. scalar [ˈskeilə]	adj.	梯状的，分等级的，数量的，标量的
	n.	数量，标量
17. lag [læg]	n.	落后，迟延，囚犯，桶板，防护套
	adj.	最后的
	vi.	缓缓而行，滞后
	vt.	落后于
18. optimal [ˈɔptiməl]	adj.	最佳的，最理想的

19. measurable [ˈmeʒərəbl]	adj.	可测量的
20. observable [əbˈzəːvəbl]	adj.	能观测的
21. classical [ˈklæsikəl]	adj.	古典的，经典的，第一流的，标准的，正统派的，古典文学的
22. burden [ˈbəːdn]	n.	担子，负担，重任，要点 vt.负担

Notes

[1] And conventional techniques (root-locus and frequency-response methods, etc.) do not apply to the design of optimal and adaptive control systems, which are mostly time-varying and/or nonlinear.

并且传统方法(根轨迹法和频率响应法等)不适用于最优控制和自适应控制系统的设计，这些系统大多数是时变的和/或非线性的。

句中 which are…是非限制性定语从句，在从句中 which 代表 optimal and adaptive control systems。

[2] Because of the necessity of meeting increasingly stringent requirements on the performance of control systems, the increase in system complexity, and easy access to large-scale computers, modern control theory, which is a new approach to the analysis and design of complex control systems, has been developed since around 1960.

由于需要满足对控制系统越来越高的性能要求，以及系统复杂性的增加和大型计算机的使用方便等原因，大约从 1960 年起，现代控制理论这种设计和分析复杂系统的新方法开始发展起来。

本句比较长，the performance of control systems, the increase in system complexity, and easy access to large-scale computers 这几个短语并列，都是介词 on 的宾语。句子主语是 modern control theory，而 which is…引导非限制性定语从句，从句中的 which 代表 modern control theory。

[3] Modern control theory is contrasted with conventional control theory in that the former is applicable to MIMO systems, which may be linear or nonlinear, time-invariant or time-varying, while the latter is applicable only to linear time-invariant SISO systems.

现代控制理论与传统控制理论相比较，前者适用于 MIMO 系统，而 MIMO 系统可能是线性的也可能是非线性的，可能是定常的也可能是时变的，后者仅仅适用于线性定常的 SISO 系统。

本句中 that the former is…从句作为介词 in 的宾语，而 in that the former is…整个介词短语在句子里的作用是状语，表示动作的方式。which may be…是非限制性定语从句，在从句中 which 代表 MIMO systems。

[4] System design in classical control theory is based on trial-and-error procedures, which will not yield optimal control systems.

使用经典控制理论进行系统设计是一个基于试凑的过程，这种方法无法设计出最优控制系统。

句中 trial-and-error procedures 表示“试凑的过程”，which will not…是非限制性定语从

句，在从句中 which 代表主句中谓语的全部概念。

[5] While conventional control theory is based on the input-output relationship, or transfer function, modern control theory is based on the description of system equations in terms of n first-order differential equations, which may be combined into a first-order vector-matrix differential equation.

传统的控制理论是基于输入-输出关系或传递函数的，而现代控制理论则是基于系统的方程表示。系统方程用 n 个一阶微分方程来表示，它们可以合并成一个一阶的向量-矩阵微分方程。

句中 While 引出并列句，表示两种同时存在的事物的对比。介词短语 in terms of…作定语，修饰 system equations，which may be…是非限制性定语从句，在从句中 which 代表 n first-order differential equations。

Translating Skills 定语从句的翻译

科技英语中定语从句极为常见。定语从句也叫关系分句，是一种由关系词引导的分句形式的后置修饰语。关系分句所修饰的先行词和在句中作某种成分的关系代词、关系副词构成了定语从句的主要特征。不管一个句子有多长，句子里套有几个定语从句，是否定语从句紧随先行词之后，其基本类型有两种——限制性定语从句和非限制性定语从句。科技英语中使用定语从句能使结构紧凑，语义连贯，逻辑性强。但同时也会面临一个问题，即如果不能准确找出定语从句所修饰的先行词，理解之间的关系，就会产生误译甚至错译。因此在英汉翻译的过程中，首先通读句子，进行语法分析，借助专业知识，依靠上下文，准确理解句子所传达的信息和内涵意义。然后依据从句、先行词和主干句之间的关系，适当翻译。

1. 翻译成定语-中心语的关系

大多数的简单限制性定语从句和并列限制定语从句常翻译成带“的”字结构的定语，与先行词构成定语-中心语的关系。也有部分的非限制性定语从句可采用这种翻译方法。

(1) **A motor which is too small** would be subject to frequent overload.
过小的电动机时常会发生过载。

(2) **The degree to which they impede the flow of current** is called resistance.
阻碍电流流动的程度叫电阻。

(3) It is that part of the state space **in which asymptotically stable trajectories originate.**
它是**引出渐近稳定轨迹的**状态空间的一部分。

2. 翻译成汉语的并列关系

当定语从句结构复杂，翻译成定语-中心语的关系不符合汉语的表达习惯时，可采用重复或省略英语先行词或先行词所代表的含义的方法，把定语从句译成后置或前置的并列分句。

(4) 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。**

(5) A rocket is independent of air because it contains **an explosive mixture which consists both of a fuel to be burned and a supply of oxygen.**

火箭飞行依赖空气，因为它本身装有爆炸混合物，**这种混合物是由待燃烧的燃料和氧气组成的。**

3.翻译成汉语的同位关系

英语的定语从句和汉语的同位语关系密切，在英汉互译的过程中往往可以相互转换。

(6) **Hydrogen, which is the lightest element,** has only one electron.

最轻的元素氢只有一个电子。

(7) The second method of Liapunov **(which is also called the direct method of Liapunov)** is the most general method for the determination of stability of nonlinear and/or time-varying systems.

李雅普诺夫第 2 方法**(也称为李雅普诺夫直接法)** 是确定非线性和/或时变系统稳定性的最一般的方法。

4. 翻译成汉语的动宾关系

有时定语从句和先行词之间存在着逻辑上的动宾关系，译成汉语时，可把先行词汉译成英语定语从句里谓语动词的宾语，构成汉语的动宾关系。

(8) There are **three steps which must be taken** before we graduate from the integrated circuit technology.

我们要完全掌握集成电路工艺，必须**采取三项措施**。

5. 翻译成汉语的主谓关系

有时定语从句和先行词之间存在着逻辑上的主谓关系(特别在 There be 句型中)，译成汉语时，可把先行词汉译成英语定语从句里谓语动词的主语，构成汉语的主谓关系。

(9) There was **not one house but (作为关系代词，相当于 which was not) was burnt down.**

所有的房子都被烧掉了。

(10) There are **some metals which possess the power** to conduct electricity and the ability **to** be magnetized.

有些金属既能导电，又能被磁化。

6. 翻译成汉语的主从偏正复句

英语中有些定语从句与主干句之间语义上相互关联，且二者之间的关系并不平等，含有因果、目的、让步、条件和假设等关系，可根据语义译成汉语的偏正复句。

(11) A body **that contains only atoms with same general properties** is called an element.

一切物质，**如果它包含的原子性质都相同**，则称为元素。

(12) Einstein, **who worked out the famous Photoelectric Theory**, won the Noble Prize.

爱因斯坦**因提出了著名的“光电理论”**而获得诺贝尔奖。.

(13) Computers, **which have many advantages,** cannot take the place of man.

计算机**虽有很多优点，**却不能代替人。

(14) The first computer used the same types of component **which made equipment very large and bulky.**

首批计算机采用同类元件，**致使设备又大又笨重。**

(15) He unnecessarily spent a lot of time introducing this book, **which the students are familiar with.**

他花了很长时间介绍这本书，其实没有必要，**因为学生们对它已经很熟悉了**。

7. 翻译成独立句

(16) One was **a violent thunderstorm**, the worst I had ever seen, **which obscured my objective.**

有一次是暴风骤雨，猛烈的程度实为我生平所仅见。**这阵暴风雨遮住了我的目标。**

Exercises

1. Translate the following into Chinese.

(1) The conventional control theory is applicable only to single input and single output (SISO) linear time-invariant (LTI) systems, while modern control theory is capable of dealing with MIMO systems.

(2) Any point in the state space represents a state of the system.

(3) The state-space methods are particularly suited for digital-computer computations because they are time-domain approaches.

(4) Perhaps you have overlooked the fact that your account for May purchases has not yet been settled.

(5) The Heavenly Lake(天池), Which is one of the world famous scenic spot, is on Tienshan Mountain(天山).

(6) Not long ago the scientists made an exciting discovery that this “waste” material could be turned into plastics.

2. Translate the following into English.

(1) 状态空间法是一种基于时域的方法，可以用来分析和设计多输入—多输出控制系统。

(2) 系统的状态变量是确定控制系统状态的最少的一组变量，在选择控制系统的状态变量时，我们通常有许多种选择。

(3) 工程师应该从繁重的计算负担中解放出来，将精力完全集中在分析问题方面。

(4) 我告诉了他这个好消息，他又告诉了其他同学。

(5) 电视装置使用的器件也可以认为是光学器件。

(6) 对于任何机器来说，如果知其输入力和输出力，就能求出其机械增益。

Reading Material　Inverted Pendulum Control

The problem of balancing a broomstick on a person's hand is similar to the problem of controlling the attitude of a missile during the initial stages of launch. This problem is the classic and intriguing problem of the inverted pendulum mounted on a cart, as shown in Fig. 12.1. The cart must be moved so that mass m is always in an upright position. The only equilibrium condition is $\theta(t)=0$ and $\dot{\theta}(t)=0$.

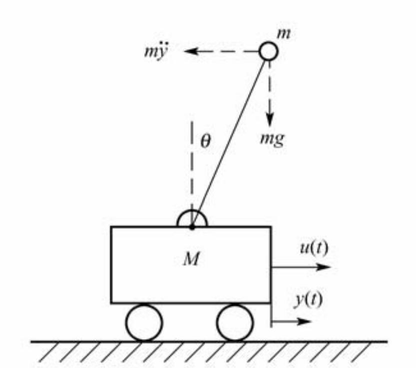


Fig. 12.1　A cart and an inverted pendulum

The state variables must be expressed in terms of the angular rotation $\theta(t)$ and the position of the cart $y(t)$. The differential equations describing the motion of the system can be obtained by writing the sum of the forces in the horizontal direction and the sum of the moments about the pivot point. We will assume that $M \gg m$ and the angle of rotation θ is very small so that the equations are linear. The sum of the forces in the horizontal direction is

$$M\ddot{y}+ml\ddot{\theta}-u(t)=0 \tag{12-1}$$

where $u(t)$ equals the force on the cart, and l is the distance from the mass m to the pivot point. The sum of the torques about the pivot point is

$$ml\ddot{y}+ml^2\ddot{\theta}-m\lg\theta=0 \tag{12-2}$$

The state variables for the two second-order equations are chosen as: $x_1=y$, $x_2=\dot{y}$, $x_3=\theta$ and $x_4=\dot{\theta}$. Then the state vector is

$$X(t)=[x_1,x_2,x_3,x_4]^{\mathrm{T}}=[y,\dot{y},\theta,\dot{\theta}]^{\mathrm{T}}$$

The equations (12-1) and (12-2) are written in terms of the state variables as

$$M\dot{x}_2+ml\dot{x}_4-u(t)=0 \tag{12-3}$$

and

$$\dot{x}_2+l\dot{x}_4-gx_3=0 \tag{12-4}$$

To obtain the necessary first-order differential equations, we solve for $l\dot{x}_4$ in equation (12-4) and substitute into equation (12-3) to obtain (note: $M \gg m$)

$$M\dot{x}_2+mgx_3=u(t) \tag{12-5}$$

Substituting $\dot{x}_2$ from equation (12-3) into equation (12-4), we have

$$ML\dot{x}_4 - Mgx_3 + u(t) = 0 \tag{12-6}$$

The state equation of the system is

$$\dot{X}(t) = AX + Bu \tag{12-7}$$

Thus the system matrices are

$$A = \begin{bmatrix} 0 & 1 & 0 & 0 \\ 0 & 0 & -(mg/M) & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & g/l & 0 \end{bmatrix}, \quad B = \begin{bmatrix} 0 \\ 1/M \\ 0 \\ -1/Ml \end{bmatrix}.$$

New Words and Phrases

1. broomstick [ˈbruːmstik]	n.	扫帚把，干扰抑制器
2. intriguing [inˈtriːgiŋ]	adj.	阴谋的，引起兴趣的，有魅力的
3. pendulum [ˈpendjuləm]	n.	摆，钟摆
4. inverted pendulum		倒立摆
5. attitude [ˈætitjuːd]	n.	姿态，姿势，态度，看法，意见
6. missile [ˈmisail]	n.	导弹
7. upright position		垂直向上位置
8. angular rotation		角旋转，角位移
9. horizontal [ˌhɔriˈzɔntl]	adj.	水平的
10. pivot [ˈpivət]	n.	枢轴

Lesson 13 Introductions to Liapunov Stability Analysis

For a given control system, stability is usually the most important thing to be determined. If the system is linear and time-invariant, many stability criteria are available. Among them are the Nyquist stability criterion, Routh's stability criterion, etc. If the system is nonlinear, or linear but time varying, however, then such stability criteria do not apply. Although a technique employing the Nyquist stability plot may be applied to a special group of nonlinear systems, the describing-function approach for the determination of stability is only approximate. Stability analysis based on the phase-plane method applies only to first-and second-order systems.

The second method of Liapunov (which is also called the direct method of Liapunov) is the most general method for the determination of stability of nonlinear and/or time-varying systems. The method applies to systems of any order.

By using the second method of Liapunov, we can determine the stability of a system without solving the state equations. This is quite advantageous because solving nonlinear and/or time-varying state equations is usually very difficult.

Although the second method of Liapunov requires considerable experience and ingenuity, it can answer the question of stability of nonlinear systems when other methods fail.

The purpose of this lesson is to present the second method of Liapunov and to illustrate its application to the stability analysis of both linear and nonlinear systems.

In this section, we first give definitions of a system, an equilibrium state, stability, asymptotic stability, and instability. Then we define the definiteness, semi-definiteness, and indefiniteness of scalar functions.

System. The system we consider in this section is defined by

$$\boldsymbol{x}' = \boldsymbol{f}(\boldsymbol{x},\ t) \tag{13-1}$$

where $\boldsymbol{x}$ is a state vector (n-dimensional vector) and $\boldsymbol{f}(\boldsymbol{x},\ t)$ is an n-dimensional vector whose elements are functions of x_1, x_2, … x_n, and t. We assume that the system of Eq.(13-1) has a unique solution starting at the given initial condition.

We shall denote the solution of Eq. (13-1) as $\phi(t;\ \boldsymbol{x}_0,\ t_0)$, where $\boldsymbol{x}=\boldsymbol{x}_0$ at $t=t_0$ and t is the observed time. Thus,

$$\phi(t_0;\ \boldsymbol{x}_0,\ t_0) = \boldsymbol{x}_0$$

Equilibrium state. In the system of Eq. (13-1) , a state x_e where

$$\boldsymbol{f}(\boldsymbol{x_e},\ t) = 0 \tag{13-2}$$

for all t is called an equilibrium state of the system. If the system is linear time-invariant, namely, if $\boldsymbol{f}(\boldsymbol{x},\ t) = \boldsymbol{A}\boldsymbol{x}$, then there exists only one equilibrium state if matrix $\boldsymbol{A}$ is nonsingular, and there exist infinitely many equilibrium states if $\boldsymbol{A}$ is singular. For nonlinear systems, there may be one or more equilibrium states. These states correspond to the constant solutions of the system ($\boldsymbol{x}=\boldsymbol{x}_e$ for all t) . Determination of the equilibrium states does not involve the solution of the differential equations of the system, Eq. (13-1) , but only the solution of Eq. (13-2) .

Any isolated equilibrium state (i.e., isolated from each other) can be shifted to the origin of the coordinates, or $\boldsymbol{f}(\boldsymbol{0}, t)=\boldsymbol{0}$, by a translation of coordinates. In this section, we shall treat stability analysis of only such states.

Stability in the sense of Liapunov. In the following, we shall denote a spherical region of radius k about an equilibrium state $\mathbf{x}_e$ as

$$\| x-\boldsymbol{x}_e \| \leqslant k$$

where $\| \boldsymbol{x}-\boldsymbol{x}_e \|$ is called the Euclidean norm and is defined by

$$\| \boldsymbol{x}-\boldsymbol{x}_e \| = [(x_1-x_{1e})^2+(x_2-x_{2e})^2+\ldots+(x_n-x_{ne})^2]^{1/2}$$

Let $S(\delta)$ consists of all points so that

$$\| \boldsymbol{x}-\boldsymbol{x}_e \| \leqslant \delta$$

and let $S(\varepsilon)$ consists of all points so that

$$\| \phi(t;\boldsymbol{x}_0,t_0)-\boldsymbol{x}_e \| \leqslant \varepsilon \quad \text{for all } t\geqslant t_0$$

An equilibrium state $\boldsymbol{x}_e$ of the system of Eq. (13-1) is said to be stable in the sense of Liapunov if, corresponding to each $S(\varepsilon)$, there is an $S(\delta)$ so that trajectories starting in $S(\delta)$ do not leave $S(\varepsilon)$ as t increases indefinitely. The real number δ depends on ε and, in general, also depends on t_0. If δ does not depend on t_0, the equilibrium state is said to be uniformly stable.

What we have stated here is that we first choose the region $S(\varepsilon)$, and for each $S(\varepsilon)$, there must be a region $S(\delta)$ so that trajectories starting within $S(\delta)$ do not leave $S(\varepsilon)$ as t increases indefinitely.

Asymptotic stability. An equilibrium state $\boldsymbol{x}_e$ of the system of Eq. (13-1) is said to be asymptotically stable if it is stable in the sense of Liapunov and if every solution starting within $S(\delta)$ converges, without leaving $S(\varepsilon)$, to $\boldsymbol{x}_e$ as t increases indefinitely.

In practice, asymptotic stability is more important than mere stability. Also since asymptotic stability is a local concept, simply to establish asymptotic stability may not mean that the system will operate properly. Some knowledge of the size of the largest region of asymptotic stability is usually necessary. This region is called the domain of attraction. It is that part of the state space in which asymptotically stable trajectories originate. In other words, every trajectory originating in the domain of attraction is asymptotically stable.

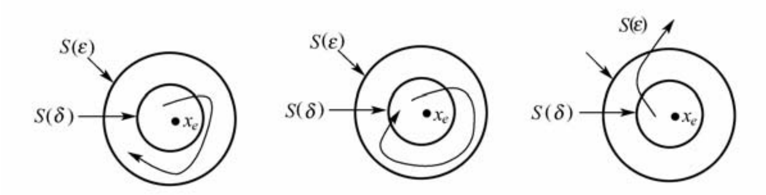
Asymptotic stability in the large. If asymptotic stability holds for all states (all points in the state space) from which trajectories originate, the equilibrium state is said to be asymptotically stable in the large. [1] That is, the equilibrium state $\boldsymbol{x}_e$ of the system given by Eq. (13-1) is said to be asymptotically stable in the large if it stable and if every solution converges to $\boldsymbol{x}_e$ as t increases indefinitely. Obviously a necessary condition for asymptotic stability in the large is that there be only one equilibrium state in the whole state space.

In control engineering problems, a desirable feature is asymptotic stability in the large. If the equilibrium state is not asymptotically stable in the large, then the problem becomes that of determining the largest region of asymptotic stability. This is usually very difficult. For all practical purposes, however, it is sufficient to determine a region of asymptotic stability large enough so that no disturbance will exceed it. [2]

Instability. An equilibrium state $\boldsymbol{x}_e$ is said to be unstable if for some real number $\varepsilon > 0$ and real number $\delta > 0$, no matter how small, there is always a state $\boldsymbol{x}_0$ in $S(\delta)$ so that the trajectory starting at this state leaves $S(\varepsilon)$.

Graphical representation of stability, asymptotic stability, and instability. A graphical representation of the foregoing definitions will clarify their notions.

Let us consider the two-dimensional case. Fig. 13.1(a) , (b) , and (c) show equilibrium states and typical trajectories corresponding to stability, asymptotic stability, and instability, respectively. In Fig. 13.1(a) , (b) , or (c) , the region $S(\delta)$ bounds the initial state $\boldsymbol{x}_0$, and the region $S(\varepsilon)$ corresponds to the boundary for the trajectory starting at $\boldsymbol{x}_0$.



(a)　(b)　(c)

Fig. 13.1　Typical trajectories corresponding to stability, asymptotic stability, and instability

Note that the foregoing definitions do not specify the exact region of allowable initial conditions. Thus the definitions apply to the neighborhood of the equilibrium state, unless $S(\varepsilon)$ corresponds to the entire state plane.

Note that in Fig. 13.1(c) , the trajectory leaves $S(\varepsilon)$ and implies that the equilibrium state is unstable. We cannot, however, say that the trajectory will go to infinity since it may approach a limit cycle outside the region $S(\varepsilon)$. (If a linear tome-invariant system is unstable, trajectories starting near the unstable equilibrium state go to infinity. But in the case of nonlinear systems this is not necessarily true.)

Knowledge of the foregoing definitions is the minimum requirement for understanding the stability analysis of linear and nonlinear systems as presented in this section. [3] Note that these definitions are not the only ones defining concepts of stability of an equilibrium state. In fact, various other ways are available in the literature. For example, in classical control theory, only systems that are asymptotically stable are called stable systems, and those systems that are stable in the sense of Liapunov, but are not asymptotically stable, are called unstable.

Positive definiteness of scalar functions. A scalar function $V(x)$ is said to be positive definite in a region Ω (which includes the origin of the state space) if $V(x) > 0$ for all nonzero states x in the region Ω and $V(0) = 0$.

A time-varying function $V(x, t)$ is said to be positive definite in a region Ω (which includes the origin of the state space) if it is bounded from below by a time-invariant positive-definite function, that is, if there exists a positive definite function $V(x)$ so that

$$V(x, t) > V(x) \qquad \text{for all } t \geqslant t_0$$
$$V(0, t) = 0 \qquad \text{for all } t \geqslant t_0$$

Negative definiteness of scalar functions. A scalar function $V(x)$ is said to be negative definite if $-V(x)$ is positive definite.

Positive semidefiniteness of scalar functions. A scalar function $V(x)$ is said to be positive semidefinite if it is positive at all states in the region Ω except at the origin and at certain other states, where it is zero.

Negative semidefiniteness of scalar functions. A scalar function $V(x)$ is said to be negative definite if $-V(x)$ is positive semidefinite.

Indefiniteness of scalar functions. A scalar function $V(x)$ is said to be indefinite if in the region Ω it assumes both positive and negative values, no matter how small the region Ω is.

New Words and Phrases

1. Liapunov Stability Analysis		李雅普诺夫稳定性分析
2. Nyquist stability criterion		奈奎斯特稳定性判据
3. approximate [əˈprɔksimeit]	adj.	近似的，大约的
	v.	近似，接近，约计
4. ingenuity [ˌindʒiˈnjuːiti]	n.	机灵，独创性，精巧，灵活性
5. equilibrium [ˌiːkwiˈlibriəm]	n.	平衡，平静，均衡，保持平衡的能力，沉着，安静
6. asymptotic [ˌæsɪmpˋtɔtik]	adj.	渐近线的，渐近的
7. for all practical purposes		实际上
8. scalar [ˈskeilə]	adj.	梯状的，分等级的，数量的，标量的
	n.	数量，标量
9. dimensional [diˈmenʃənəl]	adj.	尺寸的，空间的，维数的，……维的，……度空间的
10. unique [juːˈniːk]	adj.	唯一的，无与伦比的，独特的
11. denote [diˈnəut]	vt.	指示，表示，意味着
12. matrix [ˈmeitriks]	n.	矩阵
13. nonsingular [ˈnɔnˈsiŋgjulə]	adj.	非奇异的，非退化的，满秩的
14. isolate [ˈaisəleit]	vt.	隔离，孤立，使脱离，隔绝，绝缘
15. coordinate [kəuˈɔːdinit]	n.	同等者，同等物，坐标(用复数)
16. spherical [ˈsferikəl]	adj.	球(面)的，球形的，天体的
17. radius [ˈreidjəs]	n.	(pl. radii [ˈreidiai])半径，半径范围
18. Euclidean [juːˈklɪdɪən]	adj.	欧几里得的，欧几里得几何学的

19. norm [nɔːm]　　n.　模范，典型，标准，规范，准则，范数
20. trajectory [ˈtrædʒiktəri, trəˈdʒekətəri]　　n.　[物](射线的)轨道，弹道，轨线
21. converge [kənˈvəːdʒ]　　vi.　会聚，聚合，集中于一点，收敛(at, on, upon)
22. representation [ˌreprizenˈteiʃən]　　n.　表示法，表现

Notes

[1] If asymptotic stability holds for all states (all points in the state space) from which trajectories originate, the equilibrium state is said to be asymptotically stable in the large.

对所有的状态(状态空间中的所有各点)，如果由这些状态出发的轨迹都保持渐近稳定，那就认为平衡状态在大范围内是渐近稳定的。

If 引导的是条件状语从句，句子中 which 引导的定语从句修饰 all states。

[2] For all practical purposes, however, it is sufficient to determine a region of asymptotic stability large enough so that no disturbance will exceed it.

当然，如能实际确定一个不为扰动超过的足够大的渐近稳定范围，也就足够了。

句中的不定式短语 to determine a region…作主语，it 作形式主语，so that 引导的是目的状语从句。

[3] Knowledge of the foregoing definitions is the minimum requirement for understanding the stability analysis of linear and nonlinear systems as presented in this section.

上述各个定义对于理解本节介绍的线性和非线性系统的稳定性分析，都是最低限度的知识。

Translating Skills　同位语从句的译法

同位语从句经常用连词 that(有时也用 whether) 引出，连词 that 在从句中不作任何成分，只对与其表示同位关系的名词(通常具有抽象意义)或代词作进一步的解释。翻译时可采用下述方法：

1. 把同位语从句翻译成带“的”字结构的定语

(1) The policeman expressed the opinion **that careless driving was mainly responsible for the accident.**

警察表示了**粗心驾驶是造成该事故的主要原因的**看法。

(2) **We** all know the fact **that the birth of five mascots for the 2008 Olympics is not easy.**

我们都知道 **2008 奥运吉祥物诞生不容易的**这一事实。

2. 把同位语从句按顺序译出

有些英语同位语从句的顺序和汉语的表达顺序基本一致，可大体按顺序译出。

(3) Behaviorists, say that differences in scores are due to the fact **that blacks are often**

deprived of many of the educational and other environmental advantages that whites enjoy.

行为主义者认为，成绩的差异往往是由于**黑人被剥夺了白人在教育及其他环境方面所享有的许多有利条件。**

(4) Finally I had to accept my parents' decision **that I was to be a teacher, though the occupation interested me not at all.**

最后，我不得不接受父母的决定，**去当老师，虽然我对这样的职业毫无兴趣。**

3. 增加"即"、"以为"等词或用具有解释功能的标点符号把主从句分开

(5) Today there is evidence **that the time between each of the steps in this cycle** has been shortened.

今天，有证据**表明，这一循环的每一步骤之间的时间已经缩短了。**

(6) We are thus led to the conclusion **that friction is not always something undesirable.**

因此，我们得出这样的结论**：摩擦力并非总是不必要的。**

(7) We are familiar with the idea **that all matter consists of atoms.**

我们都熟悉这样一个概念，**即一切物质都是由原子组成的。**

4. 把同位语从句翻译成汉语的宾语从句或表语从句

当被同位语从句说明的同位名词具有动作意义时，该名词常转译成汉语的动词，与同位语从句一起构成汉语的主谓结构。

(8) The scientist made his suggestion **that we should set up a new system to control air pollution.**

这位科学家建议，**应建立新的制度来控制空气污染**。

(9) Portable computers have the advantage **that they are light in weight and fast in speed.**

手提电脑的优点是**重量轻，速度快。**

Exercises

1. Translate the following into Chinese.

(1) In addition to precision digital-type indicators, alarms and annunciators also operate on a pseudodigital principle, in that they only indicate certain Go/No-Go types of situations as in the use of colored lights or horns and bells to indicate limits that have been exceeded.

(2) Indicating instruments also can be classified in term of speed which, unless associated with a rapid-recording means, must fall within the capabilities of human identification and resolution.

(3) In fact a basic amount of movement occurs during sleep which is specifically concerned with preventing muscle inactivity.

2. Translate the following into English.

(1) 热能在辐射时，转换成性质与光相似的辐射能。

(2) 据上所述，我们至少可以得出这样的一个结论：世界处于永恒的变化和运动中。

(3) 行为主义者认为，如果一个儿童在有许多刺激物的环境中成长，而这些刺激物能

够发展其作为适当反应的能力，那么这个儿童将会有更高的智力发展。

Reading Material　Indicating Instruments

Generally an indicator consists of an assembly for producing and controlling the motion of a pointer with relation to a stationary scale, or the motion of a scale with relation to fixed point or line of reference, or the presentation of data in digital form (numeric or alphanumeric) . Within this fundamental framework there are scores of variations.

Another classification would break indicating instruments down into three categories: (1) mechanical types of devices as for example, the familiar dial-type pressure gage or the rise or fall of a column of mercury in a thermometer or barometer, (2) optical types of designs where in the moving pointer may be a weightless beam of radiation, as for example, a light-beam-type galvanometer or one of the many configurations of cathode-ray tube (CRT) and associated electronic display tube indicators, and (3) combinations of electromechanical, electrooptical, and even electrochemical principles.

For convenience, indicators also may be classified as analog indicators in which all or portion of a calibrated scale is in evidence so that the observer sees the indication in continuum so to speak-against all or part of the total range within which the indicator may swing, and digital indicators in which information is indicated a piece at a time. In addition to precision digital-type indicators, alarms and annunciators also operate on a pseudodigital principle, in that they only indicate certain Go/No-Go types of situations as in the use of colored lights or horns and bells to indicate limits that have been exceeded.

There are several forms of indication, reasonably uncommon except for very specific purposes, which illustrate the ingenuity that instrument engineers have applied to data display problems. The pyrometric cone and colored crayons and paints which indicate (historically) whether or not a certain temperature range has been exceeded serve a real need in certain high-temperature measurement situations, particularly where motion, as in tunnels and kilns, is involved. Manually operated, color-matching optical pyrometers also present an unusual and interesting indicating format.

Indicating instruments also can be classified in term of speed which, unless associated with a rapid-recording means, must fall within the capabilities of human identification and resolution. Although these characteristics vary considerably from one human being to the next, the standard of 24 frames per second as projected by motion picture equipment is indicative of the human limitation in time sensing individual events. In selecting the most appropriate (including economic justification) indicating mechanism for an instrument, the designer must consider the overall response of the measuring equipment as well as the time related importance of the measured data and the operator/instrument interface — and, in doing so, thus will not overengineer or underdesign the mode of indication.

New Words and Phrases

1. alphanumeric [ˌælfənjuːˈmerik]	adj.	字母数字的，文字数字的，包括文字与数字的
2. score [skɔː, skɔə]	n.	比数，得分，二十，[pl.]许多，大量
3. category [ˈkætigəri]	n.	种类，类别，类目，[数]范畴，类型
4. dial [ˈdaiəl]	n.	刻度盘，(仪表等的) 标度盘
5. gage [geidʒ]	n.	(=gauge) 标准度量，计量器
6. mercury [ˈməːkjuri]	n.	水银，汞
7. thermometer [θəˈmɔmɪtə(r)]	n.	温度计，体温计
8. barometer [bəˈrɔmitə]	n.	晴雨表，气压计[表]
9. optical [ˈɔptikəl]	adj.	眼的，视力的，光学的
10. galvanometer [ˌgælvəˈnɔmitə]	n.	电流计，检流计
11. calibrate [ˈkælibreit]	vt.	校准，定标，标定，使标准化，(标)刻度，(定)分度
12. annunciator [əˈnʌnʃieitə]	n.	通告者，<美>信号器，报警器
13. pseudo-		表示“伪，假拟，虚”之义
14. horn [hɔːn]	n.	号角，喇叭警报器，(汽车的)喇叭
15. kiln [kiln, kil]	n.	(砖，石灰等的)窑，炉，干燥炉，窑式烘干机
16. pyrometer [ˌpaiəˈrɔmitə]	n.	[物]高温计
17. resolution [ˌrezəˈljuːʃən]	n.	决心，坚定，分辨率
18. underdesign [ˌʌndədiˈzain]	n.	欠安全的设计

Lesson 14 Introductions to Optimal Control Systems

Optimal control systems. Problems of optimal control have received a great deal of attention during the past decade owing to increasing demand for systems of high performance and to the ready availability of the digital computer.

The concept of control system optimization comprises a selection of a performance index and a design which yields the optimal control system within limits imposed by physical constraints. Such an optimal control system differs from an ideal one in that the former is the best attainable in the presence of physical constraints whereas the latter may well be an unattainable goal. [1]

Performance indexes. In solving problems of optimal control systems, we may have the goal of finding a rule for determining the present control decision, subject to certain constraints which will minimize some measure of a deviation from ideal behavior. [2] Such a measure is usually provided by a criterion of optimization, or performance index. The performance index is a function whose value indicates how well the actual performance of the system matches the desired performance. In most practical cases, system behavior is optimized by choosing the control vector in such a way that the performance index is minimized (or maximized) .

The performance index is important because it, to a large degree, determines the nature of the resulting optimal control. That is, the resulting control may be linear, nonlinear, stationary or time-varying, depending on the form of the performance index. The control engineer formulates this index based on the requirements of the problem. Thus, he influences the nature of the resulting system. The requirements of the problem usually include not only performance requirements but also restrictions on the form of control to ensure physical realizability.

The optimization process should provide not only control policies, parameter configurations which are optimal, but also a measure of the degradation in performance by the departure of the performance index function from its minimum (or maximum) value which results from the use of nonoptimal control policies. [3]

To a considerable degree, use of optimization theory in system design has been much hampered by the conflict between analytic feasibility and practical utility in the selection of the performance index. It is desirable that the criteria for optimal control originate not from a mathematical but from an applicational point of view. In general, however, the choice of a performance index involves a compromise between a meaningful evaluation of the system performance and tractable mathematical problem.

Choosing the most appropriate performance index for a given problem is very difficult, especially in complex systems. For example, consider the problem of the maximization of a payload of a space vehicle. The payload may be considered the difference between the vehicle weight after accomplishing the mission and the residual components of the vehicle, such as supporting structures, communications, and power and altitude control equipment. Maximizing the payload, therefore, will involve an optimization of both the thrust program and mission design for minimum propellant expenditures, as well as an optimal design of the components of the vehicle. In space-vehicle applications, other possible performance specifications may be minimum fuel expenditure, minimum target miss, minimum time, etc. In civilian, as differentiated from military applications of control, the prime considerations are usually economic.

Formulation of optimization problems. The quantities appearing in control system optimization problems are state variables, control variables, and system parameters. Consider, for example, a vehicle which is assumed to be a point mass traveling through space. The state variables of this system may be the three position coordinates of the vehicle, the three velocity coordinates, and the instantaneous mass of the vehicle. These state variables are generated from a set of differential equations which, in this example, may be simply Newton's equations of motion and a continuity equation relating the propellant flow to the mass loss rate of the vehicle. The control variables for this example might be the thrust magnitude of the vehicle and a set of angles defining the thrust direction. The system parameters are constants describing certain properties of the problem. Such parameters might be the exhaust velocity of the propulsion system or a prespecified time-of-thrust termination. For systems using ionic propulsion, these parameters might be the values of the exhaust velocity and the size of the power plant carried by the vehicle.

In general, the problem of optimization of control systems may be formulated if the following information is given:

(1) system state equation and output equation;

(2) control vector;

(3) constraints of the problem;

(4) performance index;

(5) system parameters.

An optimal control problem is to determine the optimal control vector $\boldsymbol{u}(t)$ within the class of allowable control vectors. This vector $\boldsymbol{u}(t)$ usually depends on initial state or initial output, desired state or desired output, nature of the constraints, and nature of the performance index.

Except for special cases, the problem may be so complicated for analytic solution that a computational solution must be obtained. In this section, we shall discuss time-optimal control systems and optimal control systems based on quadratic performance indexes.

Time-optimal control systems. Next we shall discuss two time-optimal control problems, one is, given the discrete-time system

$$\boldsymbol{x}((k+1)T) = \boldsymbol{G}(T)\boldsymbol{x}(kT) + \boldsymbol{H}(T)\boldsymbol{u}(kT)$$

where the norm of $\boldsymbol{u}(kT)$ is not bounded, find the control vector $\boldsymbol{u}(kT)$ which will bring any initial state to the origin of the state space in the minimum number of sampling periods.

Comments on optimal control systems. The system which minimizes (or maximizes) the selected performance index is, by definition, optimal. It is evident that the performance index, in reality, determines the system configuration. It is important to point out that an optimal control system under a given performance index is, in general, not optimal under other performance indexes. In addition, hardware realization of a particular optimal control law may be quite difficult and expensive. Hence it may be pointless to devote to much expense to implementing an optimal controller, which is the best in some narrow, individualistic sense. A control system is seldom designed to perform a single task completely specified beforehand. Instead, it is designed to perform a task selected at random from a complete repertory of possible tasks. In practical systems, it then may be more sensible to seek approximate optimal control laws which are not rigidly ties to a single performance index.

Strictly speaking, we should realize that a mathematically obtained optimal control system gives, in most practical situations, the ultimate performance limitation under the given performance index and is more a measuring stick than a practical goal. Therefore, before we decide whether to build the optimal control system or something inferior but simpler, we should carefully evaluate a measure of the degree to which the performance of the complex, optimal control systems exceeds that of a simpler, suboptimal one. Unless the optimal control system can be justified, we shall not build extremely complicated, optimal control systems. [4]

Once the ultimate performance limitation is found by use of optimal control theory, we should make efforts to design a simple system that is close to optimal. Keeping this in mind, we build a prototype physical system, test it and modify it until a satisfactory system is obtained which has performance characteristics close to the optimal control system synthesized by use of optimal control theory.

Questions concerning the existence of the solution to optimal control problems. It has been stated that the optimal control problem, given any initial state $\boldsymbol{x}(t_0)$, is to find an allowable control vector $\boldsymbol{u}(t)$ that transfers the state to the desired region of the state space and for which the performance index is minimized.

It is important to mention that in some cases a particular combination of plant, desired state, performance index, and constraints make optimal control impossible. This is a matter of requiring performance beyond the physical capabilities of the system.

Questions regarding the existence of an optimal control system are important since they serve to inform the designer whether or not a proposed performance index is realistic for a given system and set of constraints. Two of the most important among these questions are those of controllability and observability. In the following, we shall very briefly explain what is mean by controllability and observability.

Controllability and observability. A system is said to be controllable at time t_0 if it is possible by means of an unconstrained control vector to transfer the system from any initial state $\boldsymbol{x}(t_0)$ to any other state in a finite interval of time.

A system is said to be observable at time t_0 if, with the system in state $\boldsymbol{x}(t_0)$, it is possible to determine this state from the observation of the output over a finite time interval.

The concepts of controllability and observability were introduced by Kalman. They play an important role in the optimal control of multivariable systems. In fact, the conditions of controllability and observability may govern the existence of a complete solution to the optimal control problem.

New Words and Phrases

1. optimal [ˈɔptiməl] adj. 最佳的，最理想的，最好的
2. optimization [ˌɔptimaiˈzeiʃən] n. 优化，最优化，最佳化
3. index [ˈindeks] n.(pl. indexes, -dices [ˈindisiːz]) 索引，标志，指标，指数
4. attainable [əˈteinəbl] adj. 可到达的，可得到的
5. deviation [ˌdiːviˈeiʃən] n. 偏离，背离(from)；偏向，偏差，误差，偏航，偏差数
6. hamper [ˈhæmpə] v. 妨碍，牵制
7. compromise [ˈkɔmprəmaiz] n. 妥协，和解，妥协[折衷]办法
8. tractable [ˈtræktəbl] adj. 易驾驭的，驯良的，易管教的，易处理的
9. payload [ˈpeiˌləud] n. 有效载荷[负载]，(运输工具的)净载重量
10. vehicle [ˈviːikl] n. 车辆，运载工具，推进装置，飞行器
11. residual [riˈzidjuəl] adj. 剩余的，残留的
12. propellant [prəˈpelənt] adj. 推进的
    n. 推进物，火药，喷气燃料；推进燃料
13. velocity [viˈlɔsiti] n. 速度，速率，迅速，周转率
14. ionic [aiˈɔnik] adj. 离子的
15. quadratic [kwəˈdrætik] adj. 二次
    n. 二次方程式
16. beforehand [biˈfɔːhænd] adv. 事先，预先，提前地，超前地
17. repertory [ˈrepətəri] n. 仓库，储藏所，宝库；(尤指知识等的)储藏；库存；储藏物；目录
18. inferior [inˈfiəriə] adj. 下等的，下级的，(质量等)劣等的，差的，次的
19. suboptimal [ˈsʌbˈɔptiməl] adj. 未达最佳标准的，不是最理想的，不是最适宜的
20. prototype [ˈprəutətaip] n. 原型[体]，样机[品]，典型，样板，模范，标准

Notes

[1] The concept of control system optimization comprises a selection of a performance

index and a design which yields the optimal control system within limits imposed by physical constraints. Such an optimal control system differs from an ideal one in that the former is the best attainable in the presence of physical constraints whereas the latter may well be an unattainable goal.

控制系统优化的概念包括性能指标的选择和在物理条件限制下最优控制系统的设计这两部分。最优控制系统和理想最优控制系统的差别在于前者是在物理条件限制的情况下可达到的最好结果，而后者是不可能达到的目标。

句中 which 引导的定语从句修饰 a design。a selection of a performance index 和 a design which yields the optimal control system within limits imposed by physical constraints 是并列宾语。连词 that 引导的宾语从句作介词 in 的宾语。

[2] In solving problems of optimal control systems, we may have the goal of finding a rule for determining the present control decision, subject to certain constraints which will minimize some measure of a deviation from ideal behavior.

在解决最优控制系统的问题时，我们有可能找到一个确定现有控制策略的规则，在某些约束条件下使它偏离理想状态的偏差测量值达到极小。

[3] The optimization process should provide not only control policies, parameter configurations which are optimal, but also a measure of the degradation in performance by the departure of the performance index function from its minimum (or maximum) value which results from the use of nonoptimal control policies.

优化过程不仅提供最优控制策略和最优参数配置，还提供在应用非最优策略的条件下，性能指标函数偏离它的极小(或极大)值时也能衡量性能上降低的程度。

not only...but also…，是固定句型。翻译为不但……而且……。

[4] Therefore, before we decide whether to build the optimal control system or something inferior but simpler, we should carefully evaluate a measure of the degree to which the performance of the complex, optimal control systems exceeds that of a simpler, suboptimal one. Unless the optimal control system can be justified, we shall not build extremely complicated, optimal control systems.

因此，在决定构建最优控制系统或者决定构建性能上较差、但比较简单的控制系统之前，我们应该仔细地权衡复杂的最优控制系统优于简单的次优控制系统程度。除非最优控制系统经过充分论证，否则我们不会去构建一个极其复杂的最优控制系统。

句中 whether 引导是宾语从句，whether...or...，翻译为是……还是……，或者……或者……。

that 代指前面的 the performance。Unless 意思为除非……，引导的是条件状语从句，从句用一般现在时，主句用一般将来时。

Translating Skills　状语从句的译法

英语中，状语从句属从属结构，根据主句和从句在意义上的关系，可分为时间、地点、比较、方式、让步、条件、原因、结果和目的从句。不同的状语从句通常由不同的从属连

词引导，与主句在表达的思想内容上有主次之别，顺序一般可前可后。汉语中，表示意义上不平等关系的分句属偏正复句，包括有转折、条件、假设、因果和目的关系。一般情况下，偏句在前，正句在后。当突出正句时，偏句也可后移，这时偏句须加上关联词。因此，在英汉互译的过程中，应注意两种语言的差别，准确理解英语句子的含义，巧用汉语关联词，进行适当转换，以符合汉语的表达习惯。

1. 译成汉语的偏正复句(把英语的状语从句前置或后移)

(1) A body at rest will not move till a force is exerted on it.(时间状语从句译成汉语的条件状语)

若没有外力的作用，静止的物体不会移动。

(2) Each time you look at an object, your eyes are taking a picture.(each time 充当连词，引导时间状语从句。类似的短语有 the moment, the minute, every time, immediately, instantly, the day 等，常译成"一……就……"，"每当"等，译成汉语时，从句常置句首)

每当你对着一个物体看时，你的眼睛就是在拍一张照片。

(3) Please ring me up the minute you get the result of the experiment. (同上)

一得出试验结果，你就立即给我打电话。

(4) A signal will be shown wherever anything wrong occurs in the control system.(地点状语翻译成汉语时常放在主句之前)

无论控制系统什么部位出故障，都会给出信号。

(5) Where the volt is too large a unit, we use the millivolt or microvolt.(地点状语从句译成汉语的条件关系)

如果伏特这个单位过大，我们就用毫伏或微伏。

(6) It is hoped robots will find wide application wherever they are available.(地点状语从句译成汉语的结果从句)

人们希望机器人将得到广泛的使用，以致任何地方都可以使用。

(7) If a laser beam diffused as it goes on, it could not be used to follow a satellite or other far-away targets. (英语中的条件状语从句不管其位置在前在后，译成汉语时，通常置于句首，但有时也会置于句末)

如果激光光束前进时扩散开来，就不能用来跟踪卫星或其他远距离目标。

(8) You can go out providing that you have to finish your homework.

你可以出去，条件是你得完成家庭作业。

(9) For this reason the draughting system was as simple as possible and consistent with reasonable running efficiency, so that it could be incorporated into an applications system with the minimum of effort.(so that 引导目的状语从句，翻译时可使用关联词"以便"，"以免"，"为的是"等，语序保持不变)

由于这个原因，作图系统应该尽可能的简单并能够高效运行，以便这种整合不需要花很多精力。

(10) The inside of the earth is so hot that the rock has melted like ice.(so… that…引导结果状语从句，翻译时与汉语语序一致)

地球内部是如此之热，以致岩石都像冰一样融化了。

(11) I didn’t speak because I was afraid.(英语中原因状语从句可前可后，翻译时一般放在句首，有时也置于句末)

我没有说话，因为我害怕。

(12) Now that I have retired , I have plenty of time to care for my grandson.

既然我已退休，我可以有足够的时间照顾孙子了。(英语中原因状语从句可前可后，翻译时一般放在句首)

(13) All computers consist of five units although they are of different kinds.(英语的让步状语从句位置灵活，翻译成汉语时往往置于句首)

尽管种类各异，但所有的计算机都由 5 部分组成。

(14) He drived the car so fast as if he were an skilled driver.(由 as if 或 as though 引导的方式状语从句，翻译时常置句末)

他开车很快，像个老司机。

(15) Just as the design of an aircraft is a most complicated matter, so too is its manufacture. (由 just as 引导的方式状语从句，翻译时常置句首)

正如飞机的设计极其复杂一样，飞机的制造也十分复杂。

2. 译成汉语的联合复句

汉语的联合复句之间的关系有 5 种，其中按时间、空间和逻辑、事理的顺序说出连续的动作或相关的情况的属顺承关系，可以有关连词，也可以用意合法。而英语中这类关系会用某些状语从句、定语从句、并列句等表达。

(16) He made notes as he was listening to the lecture. (时间状语从句译成汉语的并列关系)

他边听课，边做记录。

3. 译成汉语的简单句

翻译时，为了句子通顺、易懂、紧凑，把原文中的主从复合句译成单句。这在句子的分译与合译一章已经讲过。如：

(17) When I make a speech, I get nervous.

我演讲时总是有些紧张。

(18) While we were doing the experiment, we were very careful.

我们做实验时非常认真。

(19) It so happened that he was not at home.

碰巧他不在家。

(20) This book is written in such easy English as beginners can understand.

这本书是用初学者也能读得动的浅易英文写的。

(21) I will go when I am free.

有空我就去。

(22) When a spring is tightly stretched, it is ready to do work.

拉紧的弹簧随时都可以做功。

(23) Hardly had I got home when it began to rain.

我刚一到家就下起雨来。

(24) The more, the better. (比较状语从句往往使用省略句，翻译时语序不变。)

越多越好。

(25) He speaks English as fluently as foreigners. (同上)

她英语说得像老外一样流利。

4. 从属连词省略翻译

注重形合的英语中的时间、原因状语从句，一般都有连接词，在翻译成意合的汉语时，往往依靠语序的先后体现，把原文中的连接词省去不译。但不能一概而论，关键看译文是否忠实通顺，符合汉语习惯。如：

(26) Because the departure was not easy, we made it brief.

告别这件事难受得很，我们就作得简短一些。

(27) He must be busy, for he did not accept the invitation.

他没有接受邀请，一定是很忙。

(28) The signal levels inside power amplifiers are so much larger than these weak inputs that even the slightest ‘leakage’ from the output back to the input may cause problems.

功率放大器中的信号幅度比微弱的输入信号大得多，即使输出的极微小的泄漏传到输入端，都会引发一些问题。

Exercises

1. Translate the following into Chinese.

(1) Although the power of man to change his environment is increasing, owing to both exponential population growth and rapid technological change, his activities cannot be seen as being immune to the influence of his physical environment.

(2) While industrial lasers today are most often used for cutting, welding, drilling and measuring, the laser’s light can be put to a much different use: separating isotopes to produce nuclear fuel.

(3) Sometimes this fall, if all goes well, a revolutionary new undersea vessel will be lowered gently into the waters of Monterey Bay for its maiden voyage.

(4) He made a speech so inspiring that everyone got excited.

(5) Cables are usually laid underground so that their life may be extended.

(6) Since information is continuously sent into the system as it becomes available, teletext is always kept up-to-date.

2. Translate the following into English.

(1) 尽管温度可高达摄氏 400 度，水却因为处于高压之下而不会沸腾。

(2) 对于放大了的信号，必须作进一步的处理后，才能把它们馈送到发射天线上去。

(3) 在量子世界里，我们就需要将广义相对论进行扩充，使得这一理论中不仅包含引力的宏观特性，还同时包含引力的微观特性。

(4) 如果你努力工作，你会成为一个出色的工程师。
(5) 大学毕业后，他一直从事摄影工作。
(6) 看到算盘在集成电路的魔法前还能与之抗衡，我感到高兴。

Reading Material Introductions to Control Engineering

Whenever energy is to be used purposefully, some form of control is necessary. In recent times there has been a considerable advance made in the art of automatic control.

In a simple centrifugal governor system, variations in engine speed are detected and used to control the pressure of the steam entering the engine. Under steady conditions the moment of the weight of the metal spheres balances that due to the centrifugal force and the steam valve opening is just sufficient to maintain the engine speed at the required level. When an extra load torque is applied to the engine, its speed will tend to fall, the centrifugal force will decreased and the metal spheres will tend to fall slightly. Their height controls the opening of the steam valve which now opens further to allow a greater steam pressure on the engine. The speed thus tends to rise, counteracting the original tendency for the speed to fall. If the extra load is removed, the reverse process takes place, the metal spheres tend to rise slightly, so tending to close the steam valve and counteracting any tendency for the speed to rise.

It is obviously that without the governor the speed would fall considerably on land. However, in a correctly designed system with a governor, the fall in speed would be very much less. The real problem in the synthesis of all systems of this type is to prevent excessive oscillation but at the same time produce good “regulation”. Regulators are used to keep some physical quantity constant (e.g. speed, voltage, liquid level, humidity, etc.) regardless of load variation. A good regulator has only very small regulation.

The 1914—1918 war caused military engineers to realize that to win wars it is necessary to position heavy masses (e.g. ships and guns) precisely and quickly. Classic work was performed by N. Minorsky in the USA in the early 1920’s on the automatic steering of ships and the automatic positioning of guns on board ships. In 1934, H.L.Hazen first defined a servomechanism as a power-amplifying device in which the amplifier element driving the output is actuated by the difference between the input to the servo and its output. More recently it has been suggested that the term “servomechanism” or “servo” be restricted to a feedback control system in which the controlled variable is mechanical position.

The automatic control of various large-scale industrial processes, as encountered in the manufacture and treatment of chemicals, food and metals, has emerged during the last thirty years as an extremely important part of the general field of control engineering. In the initial stages of development it was scarcely realized that the theory of process control was intimately related to the theory of servomechanisms and regulators. Even nowadays complete academic design of process control systems is virtually impossible owing to our poor understanding of the dynamics of processes. Servomechanisms and regulators are usually used as examples to illustrate the methods of analysis. These methods are, however, often applicable to process control systems.

New Words and Phrases

1. art [ɑːt] n. 艺术，艺术品，美术，技术，技巧，权术，手段，巧妙
2. centrifugal [senˈtrifjugəl] adj. 离心的，利用离心力的
3. sphere [sfiə] n. 球，球形，球体，球面
4. valve [vælv] n. 阀，电子管，真空管
5. torque [tɔːk] n. 扭(力)矩，转(力)矩
6. counteract [ˌkauntəˈrækt] vt. 抵抗，抵制，阻碍，消除……的作用，反作用，中和，抵消
7. servomechanism [ˈsəːvəuˈmekənizəm] n. 伺服机构，随动系统[机构]，跟踪系统
8. intimate [ˈintimit] adj. 密切的，亲密的
9. academic [ˌækəˈdemik] adj. 学院的，理论的
10. dynamics [daiˈnæmiks] n. 力学，动力学，动态
11. steer [stiə] v. 掌舵，驾驶
12. owing to 由于，因……之缘故

Lesson 15 Introductions to Sensors

This is an introduction to some of the physical principles that underlie sensors in instrument systems. It is not intended to be definitive, or very detailed, but to give the reader an idea of what is readily achievable with the various systems. I'd welcome corrections and suggestions for improvements.

Electrical resistance is the easiest electrical property to measure precisely over a wide range at moderate cost. A simple digital multimeter costing a few tens of dollars can measure resistances in the range 10 ohm to 10 megohm with a precision of about 1% using a two-wire technique (Fig. 15.1).

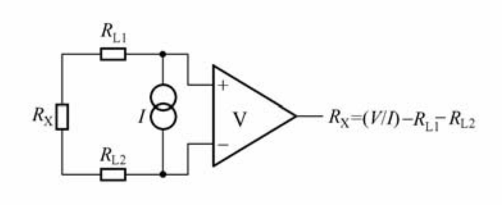


Fig. 15.1 2-Wire Resistance Measurement

The precision of the two-wire method is limited by uncertainties in the values of the lead resistances R_{L1} and R_{L2}.

Providing R_{L1} and R_{L2} are well matched, three-wire techniques can be used. Circuit in Fig. 15.2 employs two matched current sources, I1 and I2, to eliminate the effects of lead resistance. Circuit in Fig. 15.3 is an AC-bridge that is in balance when $R_X = R_Y$. If a lock-in amplifier is used as a null-detector, determination of R_X with an extremely low excitation current is possible.

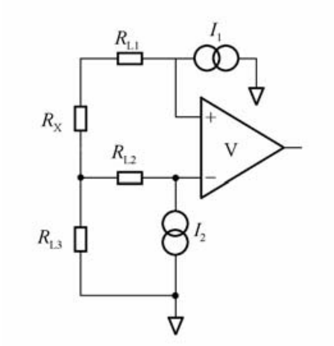


Fig. 15.2 3-Wire Resistance Measurement

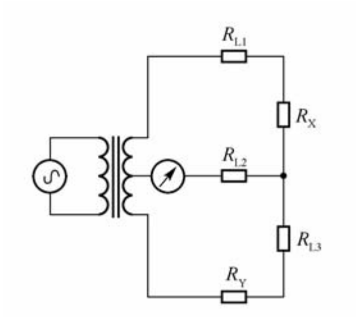


Fig. 15.3 Bridge Method

The 4-Wire "Kelvin" method (circuit in Fig. 15.4) is used in difficult cases when lead resistances vary, R_X is very small, or when very high accuracy is required. The method is immune to the influence of lead resistance and is limited by the quality of the constant current source and voltage measurement. Thermoelectric voltages can be eliminated by averaging two measurements with the polarity of the excitation current reversed.

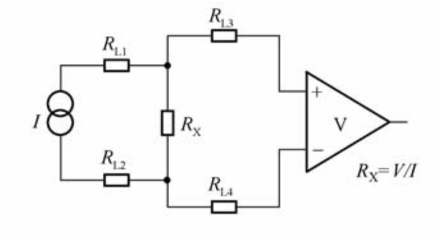


Fig. 15.4 4-Wire "Kelvin" Resistance Measurement

Resistance Temperature Detectors (RTD) exploit the fact that the electrical resistivity of metals and alloys varies in a reproducible way with temperature. Platinum, with a temperature coefficient of about 0.0039 K^{-1}, is the most popular material used in this application. An RTD consists of a coil of wire, or a thin-film, with four-wire electrical connections supported in a way that is a compromise between robustness and thermal time-constant [1]. RTDs have excellent accuracy (e.g. 0.025 K at room temperature) over a wide temperature range. At cryogenic temperatures the resistance of metals becomes constant, and it is usual to use a sample of doped-semiconductor as the sensing element. When using RTDs, it is always important to check that the measured resistance is independent of excitation current in order to avoid errors caused by self-heating.

Strain Gauges

At constant temperature, the resistance R of a metal or semiconductor element of area A, length l, resistivity ρ, is

$$R = l\rho/A \tag{15-1}$$

and when the element is strained this changes by an amount

$$\Delta R = \left[\frac{\partial R}{\partial l}\right]\Delta l + \left[\frac{\partial R}{\partial \rho}\right]\Delta\rho + \left[\frac{\partial R}{\partial A}\right]\Delta A = \frac{\rho}{A}\Delta l + \frac{l}{A}\Delta\rho + \frac{\rho l}{A^2}\Delta A$$

$$\therefore \frac{\Delta R}{R} = \frac{\Delta l}{l} + \frac{\Delta\rho}{\rho} - \frac{\Delta A}{A}$$

A typical strain gauge consists of a metal foil, photo-etched to form a serpentine pattern, and mounted on a resin backing film. This is then attached to the structure to be monitored with adhesive. Metal sensor-elements are dominated by the geometric terms in the above equation and therefore they are relatively temperature independent and have a modest gauge factor (i.e. responsivity) of about 2. Semiconductor elements can exploit a large piezoresistive effect yielding gauge factors of ca 150. However, this is at the expense of temperature stability and some sort of compensation scheme is usually required in practice.

Strain gauges are widely used in many applications; they are small, cheap, sensitive and reliable, and many variables (e.g. pressure) can be used to cause strain.

Capacitance can also be measured over a wide range at moderate cost. A simple hand-held meter and some digital multimeters use a two-wire technique to measure capacitances in the range 100 pF to 1 F with an accuracy of about 1%.[2] Such meters often work by incorporating the unknown capacitor into a relaxation oscillator such as the ramp generator experiment. This charges the unknown capacitance with a known constant current, and the capacitance is calculated from the charging time required for it to reach the threshold voltage.

Stray capacitance, typically in the range 10 pF to 10 pF, is the major source of error in capacitance measurements, and must be dealt with using “guarding” techniques. A high impedance terminal is guarded by ensuring that it is surrounded by conductors held at the same potential by some means. Circuit in Fig. 15.5 shows how the influence of the stray capacitance to ground associated with a piece of coaxial cable can be eliminated by reconnecting its shield to a low impedance node. [3]

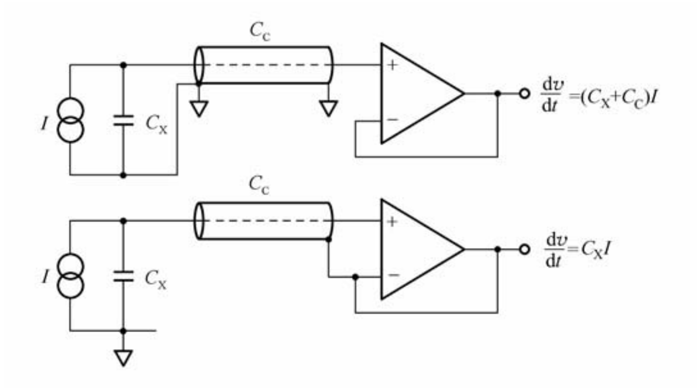


Fig. 15.5　Unguarded (top) and guarded (bottom) configurations

With care (and about 10,000 dollars worth of equipment) it is possible to measure absolute capacitance values to 1 part in 10^8 using so-called “AC coaxial bridges”.

Capacitive sensors are the most precise of all electrical sensors. A capacitive sensor can be designed to be:

(1) non-dissipative and therefore free of thermal noise;

(2) free from self-heating;

(3) linear with applied voltage;

(4) temperature independent.

Simple but very precise sensors can be based on the change in geometry of a pair of capacitor plates, or on the effects of introducing conducting material into the capacitor gap.

Capacitive pressure sensors use a thin diaphragm, usually metal or metal-coated quartz, as one plate of a capacitor. The diaphragm is exposed to the process pressure on one side and to a reference pressure on the other. Changes in pressure cause it to deflect and change the capacitance. The change may or may not be linear with pressure and is typically a few percent of the total capacitance. The capacitance can be monitored by using it to control the frequency of an oscillator or to vary the coupling of an AC signal.[4] It is good practice to keep the signal-conditioning electronics close to the sensor in order to mitigate the adverse effects of stray capacitance. Circuit in Fig. 15.6 is a schematic example.

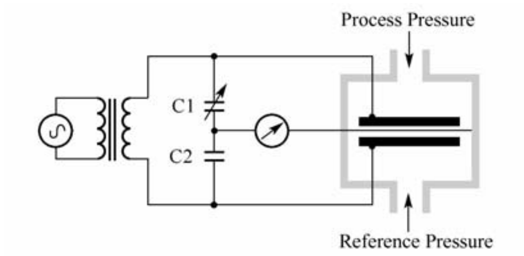


Fig. 15.6 Schematic capacitive pressure sensor

Developments in silicon-based micro-machine technology have lead to several significant improvements in the performance and usability of capacitive pressure sensors.

New Words and Phrases

1. principle [ˈprinsəpl]	n.	原则，原理
2. property [prɔpəti]	n.	特性，性能，属性
3. multimeter [ˈmʌltimiːtə]	n.	[物]万用表
4. megohm [ˈmegəum]	n.	兆欧姆
5. match [mætʃ]	vt.	和……相配，和……相称
6. amplifier [ˈæmpliˌfaiə]	n.	放大器
7. detector [diˈtektə]	n.	探测器，检验器，检波器
8. excitation [ˌeksiˈteiʃən]	n.	刺激，激励，兴奋
9. Kelvin [ˈkelvin]	adj.	[物]绝对温标的，开尔文温标的
10.thermoelectric [ˌθəːməuiˈlektrik]	adj.	[物]温差电的，热电的
11.polarity [pəuˈlæriti]	n.	两极，极性，磁性引力，相反，对立
12.resistivity [ˌriːzisˈtiviti]	n.	抵抗力，[电]电阻率
13.silicon [ˈsilikən]	n.	[化]硅
14.robustness [rəˈbʌst]	n.	强壮，强健，坚实
15.cryogenic [ˌkraiəuˈdʒenik]	adj.	低温的，致冷的
16.semiconductor [ˈsemikənˈdʌktə]	n.	[电]半导体
17.strain [strein]	vi.	扭歪，弯曲，(因用力而)变形
18.gauge [gedʒ]	n.	测量仪器，规，表，计

19.amount [ə'maunt]	n.	总数，总额，数量
20.serpentine ['sə:pəntain]	adj.	蛇的，弯弯曲曲的
21.resin ['rezin]	n.	树脂，合成树脂
22.monitor ['mɔnitə]	n.	监听器，监视器，监控器
23.geometric [dʒiə'metrik]	adj.	几何(学)的
24.piezoresistive [pai,i:zəuri'zistiv]	adj.	压阻(现象)的
25.capacitance [kə'pæsitəns]	n.	[电]电容，电流容量
26.meter ['mi:tə]	n.	计量器，仪表
27.oscillator ['ɔsileitə]	n.	振荡器，振动器
28.ramp [ræmp]	n.	斜面，斜坡，坡道
29.generator ['dʒenəreitə]	n.	发电机，发生器
30.threshold ['θreʃhəuld]	n.	开始，开端，极限
31.stray [strei]	vt.	偏离
32.impedance [im'pi:dəns]	n.	阻抗
33.terminal ['tə:minl]	n.	末端，终点，极限
34.coaxial [kəu'æksəl]	adj.	[数]同轴的
35.dissipative ['disipeitiv]	adj.	分散的
36.linear ['liniə]	adj.	[数]一次的，线性的
37.diaphragm ['daiəfræm]	n.	[解]横膈膜
38.quartz [kwɔ:ts]	n.	[矿]石英
39.schematic [ski'mætik]	adj.	概要的

Notes

[1] An RTD consists of a coil of wire, or a thin-film, with four-wire electrical connections supported in a way that is a compromise between robustness and thermal time-constant.

一个电阻式温度探测器包括一个线圈或薄碳膜，采用四线电子连接，并且是耐磨和恒温的一种折衷。

句中 that 引导的宾语从句修饰动词 support 的宾语 way。

[2] A simple hand-held meter and some digital multimeters use a two-wire technique to measure capacitances in the range 100 pF to 1 F with an accuracy of about 1%.

一个简单的手持仪表和几个数字万用表可通过使用两线技术测量范围从 100 pF 到 1 F 的电容，同时可达到 1%的精度。

介词短语 in the range 修饰动词 measure 的宾语 capacitances。

[3] Circuit in Fig.15.5 shows how the influence of the stray capacitance to ground associated with a piece of coaxial cable can be eliminated by reconnecting its shield to a low impedance node.

图 15.5 说明了一段同轴电缆对地寄生电容的影响是如何通过将屏蔽线与一个低阻抗点连接而被消除的。

省略 which 的定语从句(that)can be eliminated 修饰宾语 the influence。

(4) The capacitance can be monitored by using it to control the frequency of an oscillator or to vary the coupling of an AC signal.

电容能够通过用它控制振荡器的频率或者改变交流信号的偶合而被控制。

介词短语 by using it 修饰动词 monitor。

Translating Skills 动词的翻译

动词(verb) 是指表示人或事物的动作、行为、发展和变化的词。英语中的动词用法复杂、灵活，形式多样。有及物动词和不及物动词之分，前者可直接跟宾语，后者不能跟宾语；有 ed 形式和 ing 形式，前者有完成被动意义，后者有进行主动意义；有不同的语态和时态，前者有主动和被动之分，后者有 16 种时态；有不同的语气，有陈述、祈使和虚拟语气；有由名词转化来的动词。因此在翻译时应根据不同的情况和汉语的表达习惯，结合不同的上下文灵活处理，把译文的意义忠实顺畅的传递出来，从而保证译文信息传递的准确性和真实性。

1. 转换词类

(1) Honesty has always **characterized** the relationship between the two countries.

这两国之间的关系有一个**特点**，就是以诚相待。(有些英语中的动词翻译成汉语时常转换成名词，适当加词翻译，这类词有表示印象、态度、特点和地位的词，像 impress,behave, characterize, figure 等。)

(2) The new technology **is based on** the behavior of electrons in layers of semiconductor materials only a few millionths of a millimeter thick.

这种新技术的**基础**是电子在仅有几个毫微米的半导体材料层中的奇特性能。(动词转换成名词，增加“是”充当句子的谓语。)

(3) He **objected** that the project is not practical.

他**反对的理由**是：这个项目不现实。(动词转换成名词，增加“是”充当句子的谓语)

(4) He **roared** , which threatened his children away.

他的**大吼**吓走了他的孩子。(动词转换成名词，与后面的定语从句合译成一个简单句)

(5)The question of how to lower energy consumption **has not been settled**.

如何降低能耗的问题还没有**得到解决**。(有些被动语态的谓语动词转换成汉语的受动词+名词的形式。)

2. 引申词义

(6) The interference **worked** much instability in the system.

干扰给系统**造成**了很大的不稳定性。(据上下文)

(7) Vibration has **worked** some connection loose.

震动**使**一些接线松了。(据上下文，符合汉语习惯)

(8) No **work** could be done without energy.

没有**能量**就不能做功。(据所属专业进行翻译)

3. 转换成分

(9) A sketch **serves** to express one's idea graphically.

草图的**作用**就是把人们的想法用图表示出来。(有些谓语动词很难直接翻译成符合汉语习惯的动词，这时就需要把英语的谓语成分进行适当转换，其他成分也相应跟着转换。该句的谓语转换成主语。)

(10) The sun **produces i**n three days more heat than all earth fuels **could** ever **produce.**

太阳在 3 天内**发出的**热量比地球上所有燃料能**发出的**热量还要多。(同上，谓语转换成定语)

4. 转换结构

(11) They **have trained** their employees in controlling the whole process from an electronic computer.

在用电子计算机控制整个操作过程方面，他们已**使自己的员工受到训练**。(动词转译成使动结构。)

(12) The infinitesimal amount of nuclear fuel **required** makes it possible to build power reactors in any part of the world.

因为**所需的**核燃料极少，所以可能把动力反应堆建在世界上的任何地方。(主谓句转偏正。)

(13) To **explore the moon's surface**, rocket were launched again and again.

为了**进行月面探测**，人们一次又一次地发射火箭。(动宾转定-中结构)

5. 增加翻译

(14) They **are waiting** for the bus.

他们**在等**公共汽车。(添加英语中空缺的时间副词。)

(15) This country **will be** strong and prosperous.

这个国家**将来会**强盛。(添加英语中空缺的时间副词)

(16) It has been years since I skated last time. I **can't skate** as fast as I **could.**

我已经有许多年没溜冰了，我**现在**溜得不如**以前**快。(添加英语中空缺的时间副词)

6. 省略翻译

(17) **I'll** come and see you tomorrow.

明天我来看你。(省略汉语中已明确的动词时态含义)

(18) The charged capacitor **behaves** as a secondary battery.

充了电的电容器就**像蓄电池一样**。(省略动词，翻译时直接用汉语的介宾短语作谓语)

(19) Television signals **have** a short range.

电视信号的传递距离**很近**。(省略动词，翻译时直接用形容词“短”作谓语，以符合汉语的习惯)

Exercise

1. Translate the following into Chinese.

(1) In Korea, most young people behaved respectfully towards the old people.

(2) The book is addressed primarily to chemical, environmental and mechanical engineers, engaged in the design and operation of equipment of air pollution control.

(3) Gases differ from solids in that the former have greater compressibility than the latter.

2.Translate the following into English.

(1) 他一直在等他的女儿，盼望着她的女儿早日回来。

(2) 大多数犹太人在二战期间受到种族迫害。

(3) 设计的目的在于自动操作，调节方便，维护简单，生产率高。

Reading Material Thermoelectric Effects and Temperature Measurement

Thermoelectric voltages are the most common source of error in low-level voltage measurements. They arise when circuit connections are made using dissimilar metals at different temperatures. In this context, two thermoelectric effects are important. Firstly, the Seebeck effect is the flow of current which arises when the junctions of a circuit made of two different metals are at different temperatures. Secondly, the Thomson effect describes the production of an electromotive force between two points at different temperatures in the same material.

Each metal-to-metal junction generates an EMF proportional to its temperature and precautions must be taken to minimize thermocouple voltages and temperature variations in low-level voltage measurements. The best connections are formed using copper-to-copper crimped connections. Table 15−1 lists thermoelectric voltages for junctions between copper and other metal commonly found in electronics.

Table 15−1 Thermoelectric voltages between copper and other metal

Copper-to-	EMF μV K^{-1} (approx)
Aluminum	5
Beryllium Copper	5
Brass	3
Copper	< 0.3
Copper-Oxide	1000
Gold	0.5
Silicon	500
Silver	0.5
Solder (Cadmium-Tin)	0.2
Solder (Tin-Lead)	5

Thermocouples are reproducible, small and cheap. It is not surprising therefore that they are commonly used to measure temperatures.

In Fig. 15.7, if the reference junction J_2 is held at a known temperature, the temperature of J_1 can be deduced from the measured voltage difference by using standard tables. Maintaining a constant reference temperature is often inconvenient but specialized integrated circuits (e.g. the AD594/5) known as “electronic cold-junctions” are available. They create and monitor the reference junction within their own packaging, include a precision DC amplifier and liberalization circuitry.

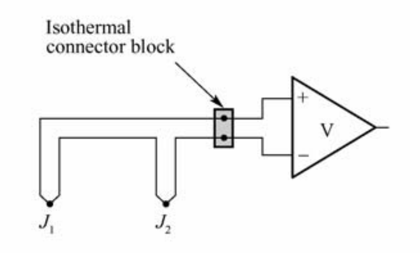


Fig. 15.7　Circuit of Thermocouples

Lesson 16 Introductions to PID Controllers

PID controllers can be stand-alone controllers (also called single loop controllers), controllers in PLCs, embedded controllers, or software in Visual Basic or C# computer programs.

PID controllers are process controllers with the following characteristics:

- Continuous process control
- Analog input (also known as “measurement” or “Process Variable” or “PV”)
- Analog output (referred to simply as “output”)
- Setpoint (SP)
- Proportional (P) , Integral (I) , and/or Derivative (D) constants

Examples of “continuous process control” are temperature, pressure, flow, and level control. For example, controlling the heating of a tank. For simple control, you have two temperature limit sensors (one low and one high) and then switch the heater on when the low temperature limit sensor turns on and then turn the heater off when the temperature rises to the high temperature limit sensor. This is similar to most home air conditioning & heating thermostats.

In contrast, the PID controller would receive input as the actual temperature and control a valve that regulates the flow of gas to the heater. The PID controller automatically finds the correct (constant) flow of gas to the heater that keeps the temperature steady at the setpoint. Instead of the temperature bouncing back and forth between two points, the temperature is held steady. If the setpoint is lowered, then the PID controller automatically reduces the amount of gas flowing to the heater. If the setpoint is raised, then the PID controller automatically increases the amount of gas flowing to the heater. Likewise the PID controller would automatically for hot, sunny days (when it is hotter outside the heater) and for cold, cloudy days.

The analog input (measurement) is called the “process variable” or “PV”. You want the PV to be a highly accurate indication of the process parameter you are trying to control. For example, if you want to maintain a temperature of ＋ or － one degree then we typically strive for at least ten times that or one-tenth of a degree. If the analog input is a 12 bit analog input and the temperature range for the sensor is 0 to 400 degrees then our “theoretical” accuracy is calculated to be 400 degrees divided by 4,096 (12 bits) ＝0.09765625 degrees. [1] We say “theoretical” because it would assume there was no noise and error in our temperature sensor, wiring, and analog converter. There are other assumptions such as linearity, etc.. The point being—with 1/10 of a degree “theoretical” accuracy—even with the usual amount of noise and other problems—one degree of accuracy should easily be attainable.

The analog output is often simply referred to as “output”. Often this is given as 0~100 percent. In this heating example, it would mean the valve is totally closed (0%) or totally open (100%) .

The setpoint (SP) is simply—what process value do you want. In this example—what temperature do you want the process at?

The PID controller's job is to maintain the output at a level so that there is no difference (error) between the process variable (PV) and the setpoint (SP) .

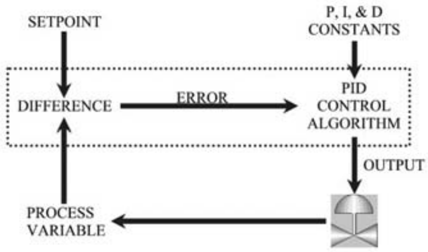


Fig. 16.1　PID controller

In Fig. 16.1, the valve could be controlling the gas going to a heater, the chilling of a cooler, the pressure in a pipe, the flow through a pipe, the level in a tank, or any other process control system.

What the PID controller is looking at is the difference (or "error") between the PV and the SP. It looks at the absolute error and the rate of change of error. Absolute error means—is there a big difference in the PV and SP or a little difference? Rate of change of error means—is the difference between the PV or SP getting smaller or larger as time goes on.

When there is a "process upset", meaning, when the process variable or the setpoint quickly changes—the PID controller has to quickly change the output to get the process variable back equal to the setpoint. [2] If you have a walk-in cooler with a PID controller and someone opens the door and walks in, the temperature (process variable) could rise very quickly. Therefore the PID controller has to increase the cooling (output) to compensate for this rise in temperature.

Once the PID controller has the process variable equal to the setpoint, a good PID controller will not vary the output. You want the output to be very steady (not changing) . If the valve (motor, or other control element) is constantly changing, instead of maintaining a constant value, this could cause more wear on the control element.

So there are these two contradictory goals. Fast response (fast change in output) when there is a "process upset", but slow response (steady output) when the PV is close to the setpoint.

Note that the output often goes past (over shoots) the steady-state output to get the process back to the setpoint. For example, a cooler may normally have its cooling valve open 34% to maintain zero degrees (after the cooler has been closed up and the temperature settled down) . If someone opens the cooler, walks in, walks around to find something, then walks back out, and then closes the cooler door—the PID controller is freaking out because the temperature may have raised 20 degrees! So it may crank the cooling valve open to 50, 75, or even 100 percent—to hurry up and cool the cooler back down—before slowly closing the cooling valve back down to 34 percent. [3]

Let's think about how to design a PID controller.

We focus on the difference (error) between the process variable (PV) and the setpoint (SP). There are three ways we can view the error.

The absolute error

This means how big is the difference between the PV and SP. If there is a small difference between the PV and the SP—then let's make a small change in the output. If there is a large difference in the PV and SP—then let's make a large change in the output. Absolute error is the "proportional" (P) component of the PID controller.

The sum of errors over time

Give us a minute and we will show why simply looking at the absolute error (proportional) only is a problem. The sum of errors over time is important and is called the "integral" (I) component of the PID controller. Every time we run the PID algorithm we add the latest error to the sum of errors. In other words Sum of Errors＝Error1＋Error2＋Error3 ＋Error4＋….

The dead time

Dead time refers to the delay between making a change in the output and seeing the change reflected in the PV. The classical example is getting your oven at the right temperature. When you first turn on the heat, it takes a while for the oven to "heat up". This is the dead time. If you set an initial temperature, wait for the oven to reach the initial temperature, and then you determine that you set the wrong temperature—then it will take a while for the oven to reach the new temperature setpoint. This is also referred to as the "derivative" (D) component of the PID controller. This holds some future changes back because the changes in the output have been made but are not reflected in the process variable yet.

Absolute Error/Proportional

One of the first ideas people usually have about designing an automatic process controller is what we call "proportional". Meaning, if the difference between the PV and SP is small—then let's make a small correction to the output. If the difference between the PV and SP is large—then let's make a larger correction to the output. This idea certainly makes sense.

We simulated a proportional only controller in Microsoft Excel. Fig. 16.2 is the chart showing the results of the first simulation (DEADTIME＝0, proportional only) :

Proportional and Integral Controllers

The integral portion of the PID controller accounts for the offset problem in a proportional only controller. We have another Excel spreadsheet that simulates a PID controller with proportional and integral control. Here (Fig. 16.3) is a chart of the first simulation with proportional and integral (DEADTIME＝0, proportional＝0.4) .

As you can tell, the PI controller is much better than just the P controller. However, dead time of zero (as shown in the graph) is not common.

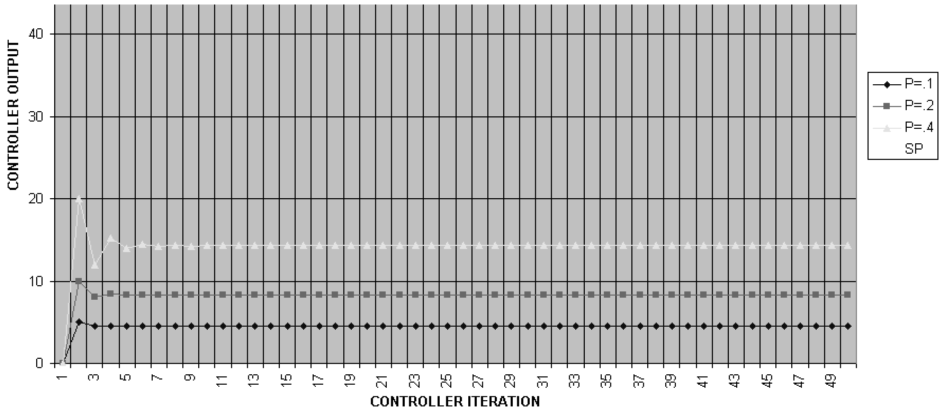


Fig. 16.2　The simulation chart

Derivative Control

Derivative control takes into consideration that if you change the output, then it takes time for that change to be reflected in the input (PV) . For example, let’s take heating of the oven. [4]

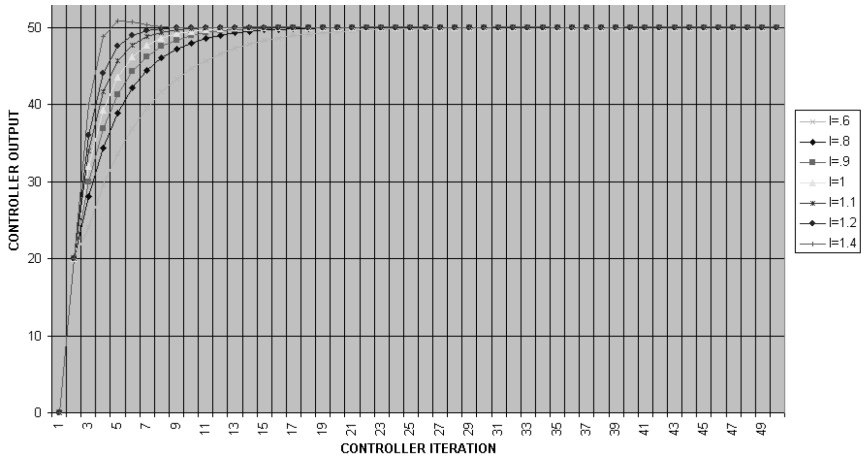


Fig. 16.3　The simulation chart

If we start turning up the gas flow, it will take time for the heat to be produced, the heat to flow around the oven, and for the temperature sensor to detect the increased heat. Derivative control sort of “holds back” the PID controller because some increase in temperature will occur without needing to increase the output further. Setting the derivative constant correctly allows you to become more aggressive with the P & I constants.

New Words and Phrases

1. make sense　　有意义，有道理；可实行的
2. integral [ˈintigrəl]　adj.　整体的，构成整体所必需的；完整的，整数的，积分的
　n.　[数]积分

3. derivative [di'rivətiv]	adj.	衍生的
	n.	派生词，衍生物，[数]导数，微商
4. thermostat ['θə:məstæt]	n.	温度自动调节器，恒温器
5. valve [vælv]	n.	阀，活门
6. compensate ['kɔmpənseit]	v	补偿，赔偿②抵消，弥补
7. parameter [pə'ræmitə]	n.	参数(量)，(尤指可以衡量或计算的)特点，特征
8. strive [straiv]	v.	努力，力求
9. linearity][ˌlini'æriti]		由 linear 派生的名词
	adj.	线的，线状的
10. motor ['məutə]	n.	(尤指使用电或内燃机的)发动机，引擎
	adj.	起动的，发动的；用发动机的
11. element ['elimənt]	n.	成分，因素，元素，[电]电阻丝
12. contradictory [ˌkɔntrə'diktəri]	adj.	相互矛盾的，相互抵触的
13. freak [fri:k]	n.	反常的事，不正常的人
14.crank [kræŋk]	n.	(可将往复运动与循环运动互为转换的)曲柄，曲轴
	v.	用曲柄启动(转动)
15.algorithm ['ælgəriðəm]	n.	算法，规则系统，编码
16.oven ['ʌvən]	n.	烤箱，烤炉
17.initial [i'niʃəl]	adj.	开始的，最初的
18.component [kəm'pəunənt]	n.	组成部分，零件；
	adj.	组成的，构成的
19.correction [kə'rekʃən]	n.	纠正，校正
20.simulate ['simjuleit]	v.	伪装，冒充，模仿，模拟
21.offset]['ɔ:fset]	n/v.	抵消，补偿
22.account for	v.	说明，解释，构成，占

Notes

[1] If the analog input is a 12 bit analog input and the temperature range for the sensor is 0 to 400 degrees then our “theoretical” accuracy is calculated to be 400 degrees divided by 4,096 (12 bits) ＝0.09765625 degrees.

如果是一个 12 位的模拟输入，并且传感器的温度范围是从 0 度到 400 度，那么我们计算的理论精确度就是 4096(12 位)除 400 度=0.097656 度。

这是一个条件从句，“for the sensor”是状语。

[2] When there is a “process upset”, meaning, when the process variable or the setpoint quickly changes－the PID controller has to quickly change the output to get the process variable back equal to the setpoint.

当存在过程干扰，同时，过程变量或给定值变化很快时—PID 控制器不得不迅速改变

输出，这样过程变量就返回到给定值。

这是一个由 when 引导的时间状语从句，“meaning”引导的是并列关系的从句，“to get the process variable back equal to the setpoint”是目的状语从句。

[3] So it may crank the cooling valve open to 50, 75, or even 100 percent－to hurry up and cool the cooler back down－before slowly closing the cooling valve back down to 34 percent.?

这样制冷阀门就可能打开 50%，75%甚至 100%—目的是赶快降低制冷器的温度—在慢慢关闭制冷阀门到它的 34%之前。

式中“to hurry up and cool the cooler back down”是解释说明部分。

[4] Derivative control takes into consideration that if you change the output, then it takes time for that change to be reflected in the input (PV) .

微分控制主要是考虑，如果你改变输出，那么要在输入(PV)处反映这个改变就需要些时间。

句中“takes into consideration”是“考虑到，斟酌”的意思，“that if you change”引导的是宾语从句，“to be reflected in the input”是省略引导词的定语从句，修饰“change”。

Translating Skills　名词的翻译

科技英语中的名词包括专业名词和普通名词。专业名词的翻译有一定的规律可循；普通名词(包括半技术词)因其在不同专业领域有特定的涵义，呈现多义性。有些名词因其所处的语法位置不同，在英译汉时，应根据前后逻辑关系适当进行词类转换和词义引申。

专业名词的翻译

1. 意译

意译是根据专业名词的涵义进行翻译，使译入语符合汉语的习惯，便于进行专业学习研究，容易被读者理解。如：

semiconductor	半导体	digital computer	数字计算机
loudspeaker	扬声器	superconductor	超导体
NC (numerical control)	数控	preamplifier	前置放大器
AC(alternate current)	交流电	modem	调制解调器
Bandwidth	带宽	LAN (local area network)	局域网
Avalanche diode	雪崩二极管	PDA(personal digital assistant)	掌上电脑

2. 音译

音译是根据英文的正确读音，用发音相同或相近的若干汉字进行翻译。当出现由几个词组合、缩写而来的专业名词、计量单位名称、新出现的材料名称、人名和地名时，专业名词常采用音译或音意结合译法，选字时尽量避免不必要的意义联想和褒贬意味，以求准确。

Radar	雷达(radio detection and ranging 无线电探测及测距设备)
Sonar	声纳(sound navigation and ranging 声波导航与测距设备)

Bit	比特(二进制信息单位)
Watt	瓦特(功率，辐射通量)
Nylon	尼龙(酰胺纤维)
Logic	逻辑
Einstein equation	爱因斯坦方程
Rifle	来复枪
Ballet	芭蕾舞
Aspirin	阿司匹林
Vitamin	维他命(维生素)

3. 像译

像译是根据专业名词所表示事物的外部特征，直接具体形象地翻译出来，准确传达出原文的信息。如：

cross-wire	十字线
X-network	X 型网络
Zigzag wave	锯齿波
Group O	O 型

4. 形译

形译是直接照抄某些代表一定概念和内在含义而非外形的字母，商品名、型号、牌号、规格、化学物质和元素名。照译：科技发展迅速，有些新出现的词无论采取上述哪一种译法都不合适，并且内行人都直接采用英语形式交流，翻译时可直接写出。如：

L-electron	**L** 层电子
NPN diode	**NPN** 二极管
X-ray examination	X 光检查
P-N-P	**P-N-P** 型晶体管

The **ICE2** would be a push-pull unit….
ICE2 型城际快车将是一种穿梭于城际间的推拉式动力列车……。

Admission Card :**IC** cards, magnetic card, CDs, and non-contact cards.
门禁卡：**IC** 卡，磁卡，光盘和非接触式卡。

Wi-fi doesn’t interfere with plane communications because it operates on a different part of the spectrum, 2.4 **GHz.**
Wi-fi 不会干扰飞机的通信，因为它采用的是不同的频段—2.4 **GHz.**

The service promises up to 700 **kbps**.
服务速度有望达到 700 **kbps**.

普通名词的翻译

1. 一词多义

在科技翻译中有些词看似简单，在不同的上下文里意义却不同。如果不结合专业技术

方面的常识仔细推敲，只管按熟悉的义项翻译出来，往往会翻译出内行人看不懂的外行话。如：

shield 的基本释义为“盾，罩，屏，防御物，保护物，吸汗垫布”。在生物学中，shield 指“盾状物，背甲，头胸甲”；在地质学中，指“地盾”如：mining shield 掘进护盾；在矿物学中，指“掩护支架”如：top shield 顶部支架；在电学中，指“屏蔽铠装”。另外还有许多技术词与 shield 有关，如：hand face shield (焊工的)面罩；electrostatic shield 静电屏。

2. 词义引申

由于英汉两种语言的明显差异，在翻译的过程中直译也许能够被理解，但译文生硬晦涩，与汉语的习惯相去甚远，这时就应对词义适当引申。这一点在第三课已经详细讲过，这里仅举几例。

There are three **steps** which must be taken before we graduate from the integrated circuit technology.

我们要完全掌握集成电路工艺，必须采取 3 项**措施**。

The car in front of me stalled and I missed **the green.**

我前头的那辆车停住了，我错过了**绿灯**。

Exercise

1. Translate the following into Chinese.

(1) There is also an unmanned robot that **Jetpod** has designed with the ability to hover.

(2) The brief pulse was enough to melt the **nanoparticles** , which could be seen under an electron microscope to swell to up to 50 **nanometers** in diameter as they coalesced.

(3) In 1979, the Romanian founded the Juran Institute for the study of quality management, and served as its first chairman.

2.Translate the following into English.

(1) 纯**尼古丁(nicotine)**，三滴就可以毒死一个成年人。

(2) 她很饿。要是换个时候，她会一直忍着到家。

(3) 建立这些大型的钢铁厂，会大大加速我国钢铁工业的发展。

Reading Material　Tuning of the PID Controller

The PID algorithm is the most popular feedback controller used within the process industries. It has been successfully used for over 50 years. It is a robust easily understood algorithm that can provide excellent control performance despite the varied dynamic characteristics of process plant.

Controller tuning involves the selection of the best values of Kc, Ti and TD (if a PID algorithm is being used). This is often a subjective procedure and is certainly process dependent. A number of methods have been proposed in the literature over the last 50 years. However, recent surveys indicate:

(1) 30 % of installed controllers operate in manual.

(2) 30 % of loops increase variability.

(3) 25 % of loops use default settings.

(4) 30 % of loops have equipment problems.

A possible explanation for this is lack of understanding of process dynamics, lack of understanding of the PID algorithm or lack of knowledge regarding effective tuning procedures. This section of the notes concentrates on PID tuning procedures. The suggestion being that if a PID can be properly tuned there is much scope to improve the operational performance of chemical process plant.

When tuning a PID algorithm, generally the aim is to match some preconceived “ideal” response profile for the closed loop system. The following response profiles are typical.

Often, with level systems exact setpoint following is not essential, hence proportional control is often used. Temperature loop dynamics can be slow because of process heat transfer lags. Dead-time is possible, especially in heat exchangers and temperature is not normally noisy. Consequently PID control is normally preferred. Flow loop dynamics are generally fast (of the order of seconds) . Control valve dynamics are normally the slowest in the loop. Flow systems are noisy. However, noise can often be dealt with simply by reducing the gain.

New Words and Phrases

1. tune [tjuːn]	n.	调子，曲调；协调
	v.	调整，调节
2. robust [rəˈbʌst]	adj.	强健的，结实有力的
3. dynamic [daiˈnæmik]	adj.	有生气的，有活力的，[专业术语]动力的，动力学的，动态的
4. characteristic [ˌkæriktəˈristik]	adj.	典型的
	n.	(人或物的)特征，特性
5. plant [plɑːnt]	n.	植物，作物，机器，设备；工厂，车间
6. procedure [prəˈsiːdʒə]	n.	程序；过程，步骤
7. loop [luːp]	n.	环路
8. preconceived [ˌp riːkənˈsiːvd]	adj.	(主张，意见等)预想的，先入为主的
9. lag [læg]	v.	滞后

Lesson 17 Introductions to Process Control

Process control system. Automatic process control is concerned with maintaining process variables, temperatures, pressures, flows, compositions, and the like at some desired operation value. Processes are dynamic in nature. Changes are always occurring, and if actions are not taken, the important process variables-those related to safety, product quality, and production rates-will not achieve design conditions.

In order to fix ideas, let us consider a heat exchanger in which a process stream is heated by condensing steam. The process is sketched in Fig. 17.1.

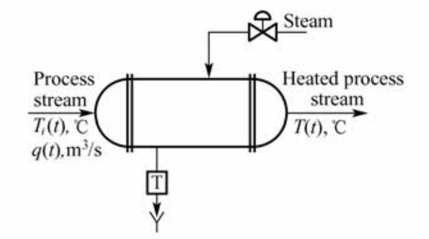


Fig. 17.1   Heat exchanger

The purpose of this unit is to heat the process fluid from some inlet temperature, $T_i(t)$, up to a certain desired outlet temperature, $T(t)$. As mentioned, the heating medium is condensing steam.

The energy gained by the process fluid is equal to the heat released by the steam, provided there are no heat losses to surroundings, [1] that is, the heat exchanger and piping are well insulated.

In this process there are many variables that can change, causing the outlet temperature to deviate from its desired value. [2] If this happens, some action must be taken to correct for this deviation. That is, the objective is to control the outlet process temperature to maintain its desired value.

One way to accomplish this objective is by first measuring the temperature $T(t)$, then comparing it to its desired value, and, based on this comparison, deciding what to do to correct for any deviation. The flow of steam can be used to correct for the deviation. This is, if the temperature is above its desired value, then the steam valve can be throttled back to cut the steam flow (energy) to the heat exchanger. If the temperature is below its desired value, then the steam valve could be opened some more to increase the steam flow (energy) to the exchanger. All of these can be done manually by the operator, and since the procedure is fairly straightforward, it should present no problem. However, since in most process plants there are hundreds of variables that must be maintained at some desired value, this correction procedure would required a tremendous number of operators. Consequently, we would like to accomplish this control automatically. That is, we want to have instruments that control the variables without requiring intervention from the operator. [3] This is what we mean by automatic process control.

To accomplish this objective a control system must be designed and implemented. A possible control system and its basic components are shown in Fig. 17.2. The first thing to do is to measure the outlet temperature of the process stream. A sensor (thermocouple, thermistors, etc) does this. This sensor is connected physically to a transmitter, which takes the output from the sensor and converts it to a signal strong enough to be transmitter to a controller. The controller then receives the signal, which is related to the temperature, and compares it with desired value. Depending on this comparison, the controller decides what to do to maintain the temperature at its desired value. Base on this decision, the controller then sends another signal to final control element, which in turn manipulates the steam flow.

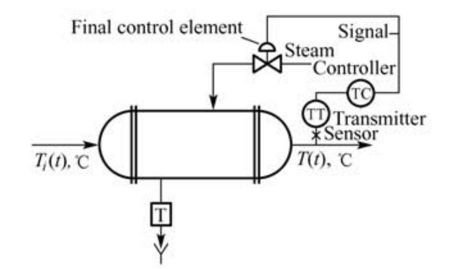


Fig. 17.2 Heat exchanger control loop

The preceding paragraph presents the four basic components of all control systems. They are

(1) sensor, also often called the primary element.

(2) transmitter, also called the secondary element.

(3) controller, the “brain” of the control system.

(4) final control system, often a control valve but not always. Other common final control elements are variable speed pumps, conveyors, and electric motors.

The importance of these components is that they perform the three basic operations that must be present in every control system. These operations are

(1) Measurement (M) : Measuring the variable to be controlled is usually done by the combination of sensor and transmitter.

(2) Decision (D) : Based on the measurement, the controller must then decide what to do to maintain the variable at its desired value.

(3) Action (A) : As a result of the controller’s decision, the system must then take an action. This is usually accomplished by the final control element.

As mentioned, these three operations, M, D, and A, must be present in every control system.

The decision-making operation in some system is rather simple, while in others it is more complex. The engineer designing a control system must be sure that the action taken affects the variable to be controlled, that is, that the action taken affects the measured value. Otherwise, the system is not controlling and will probably do more harm than good.

Important terms of automatic process control. It is necessary to define some terms used in the field of automatic process control. The first term is controlled variable. This is the variable that must be maintained or controlled at some desired value. In the preceding example, the process outlet temperature, $T(t)$,is the controlled variable. The second term is set point, the desired value of controlled variable. The manipulated variable is the variable used to maintain the controlled variable at its set point. In the example, the flow of steam is the manipulated variable. Finally, any variable that can cause the controlled variable to deviate away from set point is defined as a disturbance or upset. In most process there are a number of different disturbances. As an example, in the heat exchanger shown in Fig. 17.1, possible disturbances are inlet process temperature $T_i(t)$, the process flow $q(t)$, the quality of the energy of the steam, ambient conditions, process fluid composition, fouling, and so on. What is important here is to understand that in the process industries, most often it is because of this disturbance that automatic process control is needed. If there were no disturbances, design-operating conditions would prevail and there would be no necessity of continuously “policing” the process.

The following additional terms are also important. Open loop refers to the condition in which the controller is disconnected from the process. That is, the controller is not making the decision of how to maintain the controlled variable at set point. Another instance in which open-loop control exists is when the action (A) taken by controller does not affect the measurement (M). This is indeed a major flaw in the control system design. Close-loop control refers to the condition in which the controller is connected to the process, comparing the set point to the controlled variable and determining corrective action.

With these terms defined, the objective of an automatic process control system can be stated as follows: the objective of an automatic process control system is to use the manipulated variable to maintain the controlled variable at its point in spite of disturbances.

Regulatory and servo control. In some processes the controlled variable deviates from a constant set point because of disturbance. Regulatory control refers to systems designed to compensate for these disturbances. In some other instances the most important disturbance is the set point itself. That is the set point may be changed as a function of time (typical of this are batch processes) , and therefore the controlled variable must follow the set point. Servo control refers to control systems designed for this purpose.

Regulatory control is by far more common than servo control in the process industries. However, the basic approach to designing either of them is essentially the same. Thus, the many principles in automatic process control apply to both cases. [4]

Transmission signals. Let us now say a few words about the signal used to provide communication between instruments of control system. There are three principal types of signals used in the process industry today. The pneumatic signal, or air pressure, ranges normally between 3 and 15 psig. Less often, signals of 6 to 30 psig or 3 to 27 psig are used. The usual representation in piping and instrument diagrams (P&ID) for pneumatic signal is —//—//— .The electrical, or electronic, signal ranges normally between 4 and 20 mA. Less often 10 to 50 mA, 1 to 5 V or 0 to 10 V are used. The usual representation in P&ID's for this signal is -------. The third type of signal, which is becoming common, is the digital, or discrete, signal (zeros and ones). The use of process-control systems based on large-scale computers, minicomputers, or microprocessors is forcing increased use of this type of signal.

It is often necessary to change one type of signal into another type. This is done by a transducer. For example, there may be a need to change from an electrical signal mA, to a pneumatic signal, psig. This is done by the use of a current (I) to pneumatic (P) transducer (I/P). The input signal may be 4 to 20 mA and the output 3 to 15 psig. There are many other types of transducers: pneumatic to current (P/I) , voltage-to-pneumatic (E/P) , pneumatic-to voltage (P/E) , and so on.

Background needed for process control. To be successful in practice of automatic process control, the engineer must first understand the principles of process engineering. For the study of process automatic control it is also important to understand how processes behave dynamically. Consequently, it is necessary to develop the set of equations that describe different processes. This is called modeling. To do this, the knowledge of the basic principles mentioned in the previous paragraph and of mathematics through differential is needed. In process control the Laplace transforms are used heavily. This greatly simplifies the solution of differential equations and the dynamic analysis of processes and their control systems.

Another important "tool" for the study and practice of process control is computer simulation. Many of the equations developed to describe process are nonlinear in nature and, consequently, the most exact way to solve them is by numerical methods; this means computer solution. The computer solution of process models is called simulation.

New Words and Phrase

1. the like		同样的东西，同类的事情
2. inlet ['inlet]	n.	进口，入口，水湾，小港，插入物
3. outlet ['autlet -lit]	n.	出口；出路销路发泄的机会；排遣
4. ensue [in'sjuː]	vi.	跟着发生，继起
5. deviation [ˌdiːvi'eiʃən]	n.	偏差
6. thermocouple ['θəːməuˌkʌpl]	n.	[物]热电偶
7. thermistor [θəː'mistə]	n.	热敏电阻
8. throttle ['θrɔtl]	vt.	扼杀，压制，调节，使节流，使减速
	n.	节流阀；节流圈；风门
9. tremendous [tri'mendəs]	adj.	极大的，巨大的
10. manipulated variable		控制量

11. set point		设定值
12. fouling [ˈfauliŋ]	n.	污垢，故障，错误动作， 仪表不正确指示，结垢
13. batch process		间歇过程，断续过程，分批过程
14. psig	abbr.	pounds per square inch, gauge 磅/平方英寸(表压)
15. modeling [ˈmɔdliŋ]	n.	建模

Notes

[1] The energy gained by the process fluid is equal to the heat released by the steam, provided there are no heat losses to surroundings …

只要周围没有热损耗，过程流体获得的热量就等于蒸汽释放的热量，即热交换器和管道间的隔热性很好。

句中的过去分词短语 gained by…和 released by…作定语，分别修饰 The energy 和 the heat。provided 引导条件状语从句。

[2] In this process there are many variables that can change, causing the outlet temperature to deviate from its desired value.

很多变量在这个过程中会发生变化，继而导致出口温度偏离期望值。

句中 that 引导定语从句，修饰 many variables。分词结构 causing…作伴随状语。

[3] That is, we want to have instruments that control the variables without requiring intervention from the operator.

就是说，我们想利用无需操作人员介入就可以控制变量的设备。

句中 that 引导定语从句修饰 instruments，定语从句中 that 作主语，without 短语作状语。

[4] Thus, the many principles in automatic process control apply to both cases.

因此，自动过程控制中的许多原理对二者都适用。

Translating Skills　代词的翻译

代词具有许多特征，其中大部分是名词所没有的。顾名思义，代词“代替”名词，大部分代词的功能与名词短语相似。代词有很多种，包括人称代词、反身代词、物主代词、关系代词、疑问代词、指示代词和不定代词等。在翻译时首先要进行逻辑推理，明确代词所指代的名词或名词短语的具体含义。其次用恰当的方法准确译出，避免语意含糊不清，引起歧义。

直译

The size and cost of electronic devices have been reduced, and **their** performance, reliability, and efficiency have been greatly improved.

电子设备的体积和成本降低了，而**它们的**性能、可靠性和效率大大地提高了。

译为所指代的名词或名词短语

The high output frequencies that may be achieved allow the motor to rotate at speeds considerably in excess of **that(指示代词，代 speed)** possible by direct connection to the mains.

(PWM 信号) 可以达到的高输出频率使电机的旋转速度大大高于由直接电源供电所能得到的**转速**。

Not every material in common engineering use can be successfully welded. Some of **those (指示代词，代 material)** even, which are described as "weldable" in standards and manufacturers' catalogues , require particular processes.

不是每一种用于一般工程的材料都能成功的焊接。其中的某些**材料，**即使在一些标准中或制造厂产品目录中被列入“可焊”一类，对他们也需要用特殊的方法予以焊接。

代词省译

Different metals differ in **their(物主代词)** conductivity.

不同的金属具有不同的导电性能。

The current will blow the fuses when **it (指代 current**) reaches certain limit.

电流达到一定界限时会使熔丝熔断。

PID controllers are recommended for long time constant loops **which（关系代词）**are free of noise.

PID 控制器适用于不受噪声干扰的具有长时间常数的回路。

The little boy hides himself.

这小男孩儿躲藏起来了。

Exercises

1. Translate the following into Chinese.

(1) Switch-mode dc-to-ac inverters are used in ac-motor drives and uninterruptible ac power supplies where the objective is to produce a sinusoidal ac output whose magnitude and frequency can both be controlled.

(2) There are various schemes to pulse-width modulate the inverter switches in order to shape the output voltages to be as close to a sine wave as possible.

(3) This requires that the converter connecting the drive to the utility grid be a two-quadrant converter with a reversible dc current, which can operate as a rectifier during the motoring mode of the ac motor, and as an inverter during the braking of the motor.

(4) In square-wave inverters, the input dc voltage is controlled in order to control the magnitude of the output ac voltage, and therefore the inverter has to control only the frequency of the output voltage.

2.Translate the following into English.

(1) 如果能从核电厂获得低成本电能，电力危机就会解决。

(2) 晶体管能起真空三极管所起的大部分作用。
(3) 机床是用来进行机械加工的电动工具，如车床或铣床。
(4) 控制器是一个或一套用来控制或操纵机器或交通工具的装置。

Reading Material　Switch-mode DC-to-AC Inverters

Introduction

Switch-mode dc-to-ac inverters are used in ac-motor drives and uninterruptible ac power supplies where the objective is to produce a sinusoidal ac output whose magnitude and frequency can both be controlled. As an example, consider an ac-motor drive, shown in Fig.17.3 in a block diagram form. The dc voltage is obtained by rectifying and filtering the line voltage, most often by the diode-rectifier circuits. In an ac-motor load, the voltage at its terminals is desired to be sinusoidal and adjustable in its magnitude and frequency. This is accomplished by means of the switch-mode dc-to-ac inverter of Fig. 17.3, which accepts a dc voltage as the input and produces the desired ac voltage output.

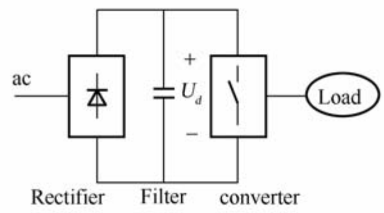


Fig. 17.3　Switch-mode inverter

To be precise, the switch-mode inverter in Fig. 17.3 is a converter through which the power flow is reversible. However, most of the time the power flow is from the dc side to the motor on the ac side, requiring an inverter mode of operation. Therefore, these switch-mode converters are often referred to as switch-mode inverters.

To slow down the ac motor in Fig. 17.3, the kinetic energy associated with the inertia of the motor and its load is recovered and the ac motor acts as a generator. During the so-called braking of the motor, the power flows from the ac side to the dc side of the switch-mode converter and it operates in a rectifier mode. The energy recovered during the braking of the ac motor can be dissipated in a resistor, which can be switched in parallel with the dc-bus capacitor for this purpose in Fig. 17.3. However, in applications where this braking is performed frequently, a better alternative is regenerative braking where the energy recovered from the motor-load inertia is fed back to the utility grid, as shown in the system of Fig. 17.4. This requires that the converter connecting the drive to the utility grid be a two-quadrant converter with a reversible dc current, which can operate as a rectifier during the motoring mode of the ac motor, and as an inverter during the braking of the motor. Such a reversible-current two-quadrant converter can be realized by two back-to-back connected line frequency thyristor converters or by means of a switch-mode converter as shown in Fig. 17.4.There are other reasons

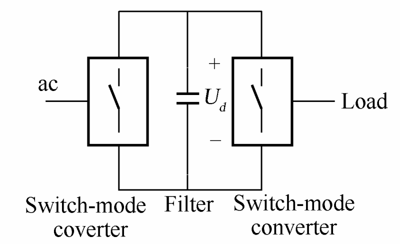


Fig17.4　Switch-mode for ac-,motor drive

for using such a switch-mode rectifier (called a rectifier because most of the time, the power flows from the ac line input to the dc bus) to interface the drive with the utility system. A detailed discussion of switch-mode rectifier is deferred to other paper, which deal with issues regarding the interfacing of power electronics equipment with the utility grid.

We will discuss inverters with single-phase and three-phase ac outputs. The input to switch-mode inverters will be assumed to be a dc-voltage source as was assumed in the block diagrams of Fig. 17.3 and Fig. 17.4. Such inverters are referred to as voltage-source inverters (VSI). The other type of inverters, currently used only for very-high-power ac-motor drives, are the current-source inverters (CSI) where the dc input to the inverter is a dc-current source. Because of their limited applications, the current-source inverters (CSI) where the dc input to the inverter is a dc-current source.

The voltage-source inverters can be further divided into the following three general categories:

1. **Pulse-Width Modulated (PWM) Inverters**. In these inverters, the input dc voltage is essentially constant in magnitude, such as in the circuit of Fig. 17.3, where a diode-rectifier is used to rectify the line voltage. Therefore, the inverter must control the magnitude and the frequency of the ac output voltages. This is achieved by pulse-width modulation (PWM) of the inverter switches and hence such inverters are called PWM inverters. There are various schemes to pulse-width modulate the inverter switches in order to shape the output voltages to be as close to a sine wave as possible.

2. **Square-Wave Inverters**. In these inverters, the input dc voltage is controlled in order to control the magnitude of the output ac voltage, and therefore the inverter has to control only the frequency of the output voltage. The output ac voltage has a waveform similar to a square wave and hence these inverters are called square-wave inverters.

3. **Single-Phase Inverters with Voltage Cancellation**. In case of inverters with single-phase output, it is possible to control the magnitude and the frequency of the inverter output voltage, even though the input to the inverter is a constant dc voltage and the inverter switches are not pulse-width modulated (and hence the output voltage waveshape is like a square wave) , therefore, these inverters combine the characteristics of the previous two inverters. It should be noted the voltage-cancellation technique works only with single-phase inverters and not with three-phase inverters.

Basic Concepts of Switch-mode Inverter

In this section, we will consider the basic requirements on the switch-mode inverters. For simplicity, let us consider a single-phase inverter, which is shown in block-diagram form in Fig. 17.5, where the output voltage of the inverter is filtered so that u_o can be assumed to be sinusoidal. Since the inverter supplies an inductive load such as an ac motor, i_o will lag u_o. The output waveforms show that during interval 1, u_o and i_o are both positive, where as during interval 3, u_o and i_o are both negative. Therefore, during intervals 1 and 3, the instantaneous power flow $p_o(=u_o i_o)$ is from the dc side to the ac side, corresponding to an inverter-mode of operation. In contrast, u_o and i_o are of opposite signs during intervals 2 and 4, and therefore p_o flows from the ac side to the dc side of the inverter, corresponding to a rectifier mode of operation. Therefore, the switch-mode inverter of Fig. 17.5 must be capable of operating in all four quadrants of the i_o-u_o plane during each cycle of the ac output. Such a four-quadrant inverter was first introduced in other section where it was shown that in a full-bridge converter, i_o is reversible and u_o can be of either polarity independent of the direction of i_o. Therefore, the full-bridge converter meets the switch-mode inverter requirements.

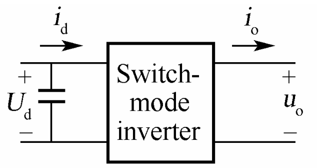


Fig. 17.5　Switch-mode for ac-motor drive

New Words and Phrases

1. inverter [in'vəːtə]	n.	反相器，逆变器，换向器
2. sinusoidal [ˌsainə`sɔidəl]	adj.	正弦的，正弦波的
3. magnitude ['mægnitjuːd]	n.	大小，数量
4. adjustable [ə'dʒʌstəb(ə)l]	adj.	可调整的
5. kinetic [kai'netik]	adj.	(运)动的，动力(学)的
6. rectifier ['rektifaiə]	n.	整流器
7. regenerative [ri'dʒenərətiv]	adj.	再生的，更生的
8. inertia [i'nəːʃjə]	n.	惯性，惯量
9. reversible [ri'vəːsəbl]	adj.	可逆的
10.quadrant ['kwɔdrənt]	n.	象限
11.line voltage		线电压
12.modulate ['mɔdjuleit]	vt.	调整，调节，(信号)调制
13.pulse-width modulated		脉宽调制
14.voltage-source inverter		电压源逆变器
15.square-wave inverter		方波逆变器
16.voltage cancellation		电压补偿
17.instantaneous [ˌinstən'teinjəs]	adj.	瞬间的，即刻的，即时的
18.regenerative braking		[电]再生制动，反馈制动
19.grid [grid]	n.	格栅，格子，栅极，高压输电网，电力网，坐标方格
20.defer [di'fəː]	vi.	推迟，延期，听从，服从
	vt.	使推迟，使延期

Lesson 18 Intelligent Control

Intelligence and intelligent systems can be characterized in a number of ways and along a number of dimensions. There are certain attributes of intelligent systems, common in many definitions, which are of particular interest to the control community.

In the following, several alternative definitions and certain essential characteristics of intelligent systems are first discussed. A brief working definition of intelligent systems that captures their common characteristics is then presented. In more detail, we start with a rather general definition of intelligent systems, we discuss levels of intelligence, and we explain the role of control in intelligent systems and outline several alternative definitions. [1] We then discuss adaptation and learning, autonomy and the necessity for efficient computational structures in intelligent systems, to deal with complexity. We conclude with a brief working characterization of intelligent (control) systems.

We start with a general characterization of intelligent systems:

An intelligent system has the ability to act appropriately in an uncertain environment, where an appropriate action is that which increases the probability of success, and success is the achievement of behavioral subgoals that support the system's ultimate goal. [2]

In order for a man-made intelligent system to act appropriately, it may emulate functions of living creatures and ultimately human mental faculties. An intelligent system can be characterized along a number of dimensions. There are degrees or levels of intelligence that can be measured along the various dimensions of intelligence. At a minimum, intelligence requires the ability to sense the environment, to make decisions and to control action. Higher levels of intelligence may include the ability to recognize objects and events, to represent knowledge in a world model, and to reason about and plan for the future. In advanced forms, intelligence provides the capacity to perceive and understand, to choose wisely, and to act successfully under a large variety of circumstances so as to survive and prosper in a complex and often hostile environment. [3] Intelligence can be observed to grow and evolve, both through growth in computational power and through accumulation of knowledge of how to sense, decide and act in a complex and changing world.

The above characterization of an intelligent system is rather general. According to this, a great number of systems can be considered intelligent. In fact, according to this definition, even a thermostat may be considered to be an intelligent system, although of low level of intelligence. It is common, however, to call a system intelligent when in fact it has a rather high level of intelligence.

There exist a number of alternative but related definitions of intelligent systems and in the following we mention several. They provide alternative, but related characterizations of intelligent systems with emphasis on systems with high degrees of intelligence.

The following definition emphasizes the fact that the system in question processes information, and it focuses on man-made systems and intelligent machines:

A. Machine intelligence is the process of analyzing, organizing and converting data into knowledge; where (machine) knowledge is defined to be the structured information acquired and applied to remove ignorance or uncertainty about a specific task pertaining to the intelligent machine. This definition leads to the principle of increasing precision with decreasing intelligence, which claims that: applying machine intelligence to a database generates a flow of knowledge, lending an analytic form to facilitate modeling of the process. [4]

Next, an intelligent system is characterized by its ability to dynamically assign subgoals and control actions in an internal or autonomous fashion:

B. Many adaptive or learning control systems can be thought of as designing a control law to meet well-defined control objectives. This activity represents the system's attempt to organize or order its "knowledge" of its own dynamical behavior, so to meet a control objective. The organization of knowledge can be seen as one important attribute of intelligence. If this organization is done autonomously by the system, then intelligence becomes a property of the system, rather than of the system's designer. This implies that systems which autonomously (self) -organize controllers with respect to an internally realized organizational principle are intelligent control systems. [5]

A procedural characterization of intelligent systems is given next:

C. Intelligence is a property of the system that emerges when the procedures of focusing attention, combinatorial search, and generalization are applied to the input information in order to produce the output. One can easily deduce that once a string of the above procedures is defined, the other levels of resolution of the structure of intelligence are growing as a result of the recursion. Having only one level structure leads to a rudimentary intelligence that is implicit in the thermostat, or to a variable-structure sliding mode controller.

The concepts of intelligence and control are closely related and the term "Intelligent Control" has a unique and distinguishable meaning. An intelligent system must define and use goals. Control is then required to move the system to these goals and to define such goals. Consequently, any intelligent system will be a control system. Conversely, intelligence is necessary to provide desirable functioning of systems under changing conditions, and it is necessary to achieve a high degree of autonomous behavior in a control system. Since control is an essential part of any intelligent system, the term "Intelligent Control Systems" is sometimes used in engineering literature instead of "Intelligent Systems" or "Intelligent Machines". The term "Intelligent Control System" simply stresses the control aspect of the intelligent system.

Below, one more alternative characterization of intelligent (control) systems is included. According to this view, a control system consists of data structures or objects (the plant models and the control goals) and processing units or methods (the control laws) :

D. An intelligent control system is designed so that it can autonomously achieve a high level goal, while its components, control goals, plant models and control laws are not completely defined, either because they were not known at the design time or because they changed unexpectedly.

There are several essential properties present in different degrees in intelligent systems. One can perceive them as intelligent system characteristics or dimensions along which different degrees or levels of intelligence can be measured.[6] Below we discuss three such characteristics that appear to be rather fundamental in intelligent control systems.

Adaptation and Learning. The ability to adapt to changing conditions is necessary in an intelligent system. Although adaptation does not necessarily require the ability to learn, for systems to be able to adapt to a wide variety of unexpected changes learning is essential. So the ability to learn is an important characteristic of (highly) intelligent systems.

Autonomy and Intelligence. Autonomy in setting and achieving goals is an important characteristic of intelligent control systems. When a system has the ability to act appropriately in an uncertain environment for extended periods of time without external intervention, it is considered to be highly autonomous. There are degrees of autonomy; an adaptive control system can be considered as a system of higher autonomy than a control system with fixed controllers, as it can cope with greater uncertainty than a fixed feedback controller. Although for low autonomy no intelligence (or “low” intelligence) is necessary, for high degrees of autonomy, intelligence in the system (or “high” degrees of intelligence) is essential.

Structures and Hierarchies. In order to cope with complexity, an intelligent system must have an appropriate functional architecture or structure for efficient analysis and evaluation of control strategies. This structure should be “sparse” and it should provide a mechanism to build levels of abstraction (resolution, granularity) or at least some form of partial ordering so to reduce complexity.[7] An approach to study intelligent machines involving entropy emphasizes such efficient computational structures. Hierarchies (that may be approximate, localized or combined in heterarchies) that are able to adapt, may serve as primary vehicles for such structures to cope with complexity. The term “hierarchies” refers to functional hierarchies, or hierarchies of range and resolution along spatial or temporal dimensions, and it does not necessarily imply hierarchical hardware. Some of these structures may be hardwired in part. To cope with changing circumstances, the ability to learn is essential, so these structures can adapt to significant, unanticipated changes.

In view of the above, a working characterization of intelligent systems (or of (highly) intelligent (control) systems or machines) that captures the essential characteristics present in any such system is:

An intelligent system must be highly adaptable to significant unanticipated changes, and so learning is essential. It must exhibit high degree of autonomy in dealing with changes. It must be able to deal with significant complexity, and this leads to certain sparse types of functional architectures such as hierarchies.

New Words and Phrases

1.adaptation [ˌædæpˈteiʃən]	n.	适应，改编，改写本
2.appropriately [əˈprəupriitli]	adv.	适当地
3.combinatorial [ˌkɔmbɪnəˋtɔːrɪəl]	adj.	组合的
4.complexity [kəmˈpleksiti]	n.	复杂(性)，复杂的事物，复杂性
5.computational [ˌkɔmpjuˈteiʃənəl]	adj.	计算的，计算机的
6.dimension [diˈmenʃən]	n.	尺寸，尺度，维(数)，度(数)，元
7.distinguishable [disˈtiŋgwiʃəbl]	adj.	可区别的，可辨别的
8.dynamical [daiˈnæmikəl]	adj.	动力(学)，有力量的
9.emulate [ˈemjuleit]	v.	仿效
10. entropy [ˈentrəpi]	n.	[物]熵，[无]平均信息量
11.exhibit [igˈzibit]	vt.	展出，陈列
	n.	陈列品，展品
	v.	展示
12.feedback [ˈfiːdbæk]	n.	反馈，反应，反馈的信息
13.fundamental [ˌfʌndəˈmentl]	adj.	基础的，基本的
	n.	基本原则，基本原理
14.granularity	n.	间隔尺寸，粒度
15.hierarchy [ˈhaiərɑːki]	n.	层次，层级
16.intelligence [inˈtelidʒəns]	n.	智力，聪明，智能，消息，信息
17.outline [ˈəutlain]	n.	大纲，轮廓，概要
	vt.	描画轮廓，略述
18.procedural [prəˈsiːdʒərəl]	adj.	程序上的
19.recursion [riˈkəːʃən]	n.	[数]递归，递归式，循环
20.rudimentary [ˌruːdəˈmentəriː]	adj.	根本的，未发展的
21.sparse [spɑːs]	adj.	稀少的，稀疏的
22.temporal dimension [ˈtempərəl diˈmenʃən]		时间因次
23.thermostat [ˈθəːməstæt]	n.	自动调温器，温度调节装置，恒温器

Notes

[1] In more detail, we start with a rather general definition of intelligent systems, we discuss levels of intelligence, and we explain the role of control in intelligent systems and outline several alternative definitions.

我们从智能系统的常规定义开始，详细地讨论智能的水平，说明智能系统中控制的作用，并概述几种不同的定义。

句中 intelligence 与 intelligent 词性不同，前者为名词，其意思是“智力”，而后者为前者的形容词形式，其意思为“聪明的，智力的”。形容词一般用来表示事物的形状、性质等，它一般用来修饰名词。

[2] An intelligent system has the ability to act appropriately in an uncertain environment, where an appropriate action is that which increases the probability of success, and success is the achievement of behavioral subgoals that support the system's ultimate goal.

智能系统具有在不确定环境中正确反应的能力，正确的反应则增加了成功的几率，从而实现了支持系统终极目标的子目标。

句中 appropriate 与 appropriately 词性不同，前者为形容词，其意思是“合适的”，而后者为前者相应的副词形式，其意思是“合适地”。副词一般用在动词、形容词前后做状语。

[3] In advanced forms, intelligence provides the capacity to perceive and understand, to choose wisely, and to act successfully under a large variety of circumstances so as to survive and prosper in a complex and often hostile environment.

在高级的形式中，智能在各种环境条件下都具有认识和理解及正确地选择和反应的能力，从而能在复杂而且通常不利的环境中得到持续发展。

句中 advanced 是 advance 的过去分词，用来作为形容词去修饰 forms。注意：英语中很多时候都涉及到用动词的现在分词或过去分词作为形容词来修饰名词。

[4] This definition leads to the principle of increasing precision with decreasing intelligence, which claims that: applying machine intelligence to a database generates a flow of knowledge, lending an analytic form to facilitate modeling of the process.

由这一定义产生了以较低的智能达到较高精度的原则，但要求应用于数据库的机器智能构造一个知识库，从而提供一种便于对象建模的解析形式。

句中 process 可作为名词时其意思为“步骤，程序”，作为动词时其意思为“处理”。注意，此种的 applying 就是 apply 的现在分词形式，它作为形容词修饰 machine intelligence。与(3)中所涉及的语法点相关。

[5] This implies that systems which autonomously (self) -organize controllers with respect to an internally realized organizational principle are intelligent control systems.

这是表示，就内部实现的结构原理而言，控制器能高度自组织的系统属于智能控制系统。

句中 organize 与 organizational 词性不同，前者为动词，其意思是“组织”，后者是形容词，其意思是“组织的”。此语法点与(1)中所述相关。

[6] There are several essential properties present in different degrees in intelligent systems. One can perceive them as intelligent system characteristics or dimensions along which different degrees or levels of intelligence can be measured

智能系统具有若干个不同层次的基本属性。人们可以根据能被度量的不同程度来将其看成是智能系统的特性或程度。

句中应注意 present，它既可作为名词、形容词也可作为动词，作为名词时其意思是“礼物”，作为形容词时其意思是“出席的，在场的，现有的”，作为动词时其意思是“赠送，提供，产生”。遇到此类词时一定要注意它在句子中究竟是什么词性，才能正确地理解文意。

[7] This structure should be “sparse” and it should provide a mechanism to build levels of

abstraction (resolution, granularity) or at least some form of partial ordering so to reduce complexity.

这一结构应该是稀疏的，并且提供一种机制来确定概括（分辨率、尺度）的标准，或至少是某些形式的局部分类，以降低复杂程度。

句中 abstraction 是动词 abstract 的相应名词形式，英语中有很多动词变为相应名词都是在动词后直接加-ion 或-ity 以及别的形式，例如句中的 complexity、resolution、granularity 等词。

Translating Skills　形容词与副词的翻译

形容词的翻译

英语形容词有不同的分类。从句法上分有定语形容词、表语形容词（常指有生物健康情况的形容词，可带补足语的形容词）、强化形容词、限制性形容词、和副词有关的形容词（指具有状语性质的形容词）、 和名词有关的形容词（由名词加后缀派生而来）；从语义上分，形容词有静态/动态、可分等级/不可分等级和本意/转意。这种区分并不绝对，因为二者往往是相联的。正因为形容词的上述表现，在翻译成汉语时，除大多数仍翻译成形容词外，也有为数不少的形容词可以转译成汉语的副词、动词或名词。

1. 译为副词

当具有状语性质的形容词所修饰的动作性名词转译成动词时，该形容词需要转译成副词。还有些形容词可根据汉语的习惯转译成汉语的副词。

(1) They gave the leader from China a **hearty** welcome.

他们很**热忱地**欢迎这位来自中国的领导人。

(2) This is **sheer** nonsense.

这**完全**是胡说。

(3) Transistors are fairly **recent** development.

晶体管是**最近**才发展起来的。

2. 译成动词

表示知觉、情欲和欲望等心理状态的形容词作表语时可转译成动词。有些作后置定语的形容词也可转译成动词。有时把修饰宾语的形容词转译成动词，和宾语构成汉语句子的动宾关系。

(4) The fact that she was **able** to send a message was a hint, but I had to be **cautious.**

她**能够**给我带个信儿这件事就是个暗示。但是我必须**小心谨慎**。

(5) I attribute my happiness to good health and **fruitful** work.

我将幸福归功于健康和**有成果**的工作。

(6) It was a very **informative** interview.

访谈中**透露**了许多**信息。**

(7) He is **indiscriminate** in reading.

他读书时**不加选择**。

(8) When people's living pace has quickened they have to spend **less** time on some things that they do for fun.

人们的生活节奏加快以后，他们不得不**缩减**花在玩乐上的时间。

3. 译成名词

英语中有些形容词加上定冠词在句中作主语或宾语，表一类人，汉译时常转译成名词；有些由名词加后缀派生而来的形容词可转译成名词；有些词在翻译时可根据汉语的习惯转译成名词。

(9) He was **eloquent** and **elegant** but soft.

他有**口才**，有**风度**，但很软弱。

(10) **Official** New York is going to object the plan.

纽约官方准备反对此项计划。

4. 译成形容词

大多数形容词都可照译成形容词，这与它修饰的名词在译成汉语时保持原来的词性有关。

(11) It is a **hard and brittle** material.

这是一种硬而脆的材料。

副词的翻译

英语副词种类繁多，很难确切定义。根据句法功能，不同的副词可以修饰形容词、副词、代词、数词、介词、介词短语、名词短语和短语动词的小品词。在英译汉时，根据所修饰的成分的翻译，可转译成汉语的名词、动词或形容词。

1. 转译成名词

当英语中动词汉译成名词时，修饰该动词的副词往往转译成汉语的形容词。某些表示事物性质、特征的形容词，可在其后加上“性”、“度”、“情况”、“上”、“下”等转译成名词。

(12) He is **physically** weak but **mentally** sound.

他**身体**虽弱，但**头脑**正常。

(13) It was **officially** announced that Korea is invited to the meeting.

官方宣布，朝鲜应邀出席会议。

(14) They have not done so well **ideologically**, however, as **organizationally.**

但是，他们的**思想工作**没有他们的**组织工作**做得好。

(15) IPC is more **reliable** than common computers.

工控机的**可靠性**比普通计算机高。

(16) They may be identified **analytically**.

他们可用分析方法加以实现。

转译成动词：副词在句中作表语或宾语补足语，有时可转换成汉语的动词。

(17) As he ran out, he forgot to have his shoes **on.**

他跑出去时，忘记了**穿**鞋子了。

(18) We must be **off** now.

我们现在得**走**了。

(19) The meeting is **over**.

会议**结束**了。

转译成形容词：当副词所修饰的动词转译成汉语的名词时，副词也相应地转译成形容词。

(20) **The visitors were** warmly **received by the hosts .**

客人受到主人的**热情**接待。

(21) He **routinely** radioed another agent on the ground.

他跟另一个地勤人员进行了**例行的**无线电联络。

(22) Prime Minister, Wen Jiabao, had prepared **meticulously** for his journey.

温家宝总理为这次出访作了**十分周密**的准备。

(23) As it is, a glass rod is charged **positively** by rubbing with silk.

事实上，用丝绸摩擦玻璃棒，玻璃棒就带**正**电荷

Exercise

1. Translate the following into Chinese.

(1) If any new problem emerges we should change our plan to make it suitable for the situation.

(2) China is a large country with a long history.

(3) Below 4℃, water is in continuous expansion instead of continuous contraction.

2. Translate the following into English.

(1) 求职者改变心态非常重要。

(2) 面对来自父母和学校的压力，这孩子对未来始终怀有忧虑。

(3) 在那些集体照中，有一张照片深远的背景不禁引起了我的注意：一股黑烟盘旋而上，升入湛蓝得无法想象的天空。

Reading Material　Introductions to Fuzzy Logic & Fuzzy Control

"Fuzzy logic" has become a common buzzword in machine control. However, the term itself inspires certain skepticism, sounding equivalent to "half-baked logic" or "bogus logic". Some other nomenclature might have been preferable, but it's too late now, and fuzzy logic is actually very straightforward.

For example, consider an antilock braking system, directed by a microcontroller chip. The microcontroller has to make decisions based on brake temperature, speed, and other variables in the system.

The variable "temperature" in this system can be divided into a range of "states", such as cold, cool, moderate, warm, hot, very hot. Defining the bounds of these states is a bit tricky. An arbitrary threshold might be set to divide "warm" from "hot", but this would result in a discontinuous change when the input value passed over that threshold.

The way around this is to make the states "fuzzy", that is, allow them to change gradually from one state to the next. You could define the input temperature states using "membership functions" such as the following:

With this scheme, the input variable's state no longer jumps abruptly from one state to the next. Instead, as the temperature changes, it loses value in one membership function while gaining value in the next. At any one time, the "truth value" of the brake temperature will almost always be in some degree part of two membership functions: 0.6 nominal and 0.4 warm, or 0.7 nominal and 0.3 cool, and so on.

The input variables in a fuzzy control system are in general mapped into by sets of membership functions similar to this, known as "fuzzy sets". The process of converting a crisp input value to a fuzzy value is called "fuzzification".

A control system may also have various types of switch, or "ON-OFF", inputs along with its analog inputs, and such switch inputs of course will always have a truth value equal to either 1 or 0, but the scheme can deal with them as simplified fuzzy functions that are either one value or another.

Given "mappings" of input variables into membership functions and truth values, the microcontroller then makes decisions for what action to take based on a set of "rules", each of the form:

IF brake temperature IS warm AND speed IS not very fast

THEN brake pressure IS slightly decreased.

In this example, the two input variables are "brake temperature" and "speed" that have values defined as fuzzy sets. The output variable, "brake pressure", is also defined by a fuzzy set that can have values like "static", "slightly increased", "slightly decreased", and so on.

This rule by itself is very puzzling since it looks like it could be used without bothering with fuzzy logic, but remember the decision is based on a set of rules:

All the rules that apply are invoked, using the membership functions and truth values obtained from the inputs, to determine the result of the rule.

This result in turn will be mapped into a membership function and truth value controlling the output variable.

These results are combined to give a specific ("crisp") answer, the actual brake pressure, a procedure known as "defuzzification".

Traditional control systems are based on mathematical models in which the control system is described using one or more differential equations that define the system response to its inputs. Such systems are often implemented as "proportional-integral-derivative (PID) " controllers.

They are the products of decades of development and theoretical analysis, and are highly effective.

If PID and other traditional control systems are so well-developed, why bother with fuzzy control? It has some advantages. In many cases, the mathematical model of the control process may not exist, or may be too “expensive” in terms of computer processing power and memory, and a system based on empirical rules may be more effective.

Furthermore, fuzzy logic is well suited to low-cost implementations based on cheap sensors, low-resolution analog-to-digital converters, and 4-bit or 8-bit one-chip microcontroller chips. Such systems can be easily upgraded by adding new rules to improve performance or add new features. In many cases, fuzzy control can be used to improve existing traditional control systems by adding an extra layer of intelligence to the current control method.

New Words and Phrases

1. bogus [ˈbəugəs]	adj.	赝造的；假货的
2. buzzword [ˈbʌzwəːd]	n.	行话
3. crisp [krisp]	adj.	脆的，易碎的
4. defuzzification	n.	反模糊化
5. empirical [emˈpirikəl]	adj.	经验主义的，[化]实验式
6. equivalent [iˈkwivələnt]	adj.	相等的，相同的
	n.	等价物
7. fuzzification	n.	模糊化
8. fuzzy [ˈfʌzi]	adj.	有绒毛的，模糊的，失真的
9. half-baked [ˈhɑːfˈbeikt]	adj.	半熟的，未完成的，不完整的
10. implement [ˈimplimənt]	n.	工具，器具
	vt.	贯彻，实现
	v.	执行
11. invoke [inˈvəuk]	v.	调用
12. nomenclature [nəuˈmenklətʃə]	n.	命名法，命名，(总称)学术用语，术语表
13. PID(proportional-integral-derivative)	n.	比例积分微分
14. theoretical [θiəˈretikəl]	adj.	理论的，假设的，推理的
15. threshold [ˈθreʃhəuld]	n.	门槛，出发点，起点；[生]阈
16. variable [ˈvɛəriəbl]	n.	变量
	adj.	易变的，可变的

Lesson 19 Introductions to PLC

A PLC (i.e. Programmable Logic Controller) is a device that was invented to replace the necessary sequential relay circuits for machine control. [1] The PLC works by looking at its inputs and depending upon their state, turning on/off its outputs. The user enters a program, usually via software or programmer, that gives the desired results.

PLCs are used in many “real world” applications. If there is industry present, chances are good that there is a PLC present. If you are involved in machining, packaging, material handling, automated assembly or countless other industries, you are probably already using them. If you are not, you are wasting money and time. Almost any application that needs some type of electrical control has a need for a PLC.

For example, let’s assume that when a switch turns on we want to turn a solenoid on for 5 seconds and then turn it off regardless of how long the switch is on for. [2] We can do this with a simple external timer. But what if the process included 10 switches and solenoids? We would need 10 external timers. What if the process also needed to count how many times the switch individually turned on? We need a lot of external counters.

As you can see, the bigger the process the more of a need we have for a PLC. We can simply program the PLC to count its inputs and turn the solenoids on for the specified time.

We will take a look at what is considered to be the “top 20” PLC instructions. It can be safely estimated that with a firm understanding of these instructions one can solve more than 80% of the applications in existence.

That’s right, more than 80%! Of course we’ll learn more than just these instructions to help you solve almost ALL your potential PLC applications.

The PLC mainly consists of a CPU, memory areas, and appropriate circuits to receive input/output data, as shown in Fig. 19.1. We can actually consider the PLC to be a box full of hundreds or thousands of separate relays, counters, timers and data storage locations. Do these counters, timers, etc. really exist? No, they don’t “physically” exist but rather they are simulated and can be considered software counters, timers, etc. These internal relays are simulated through bit locations in registers.

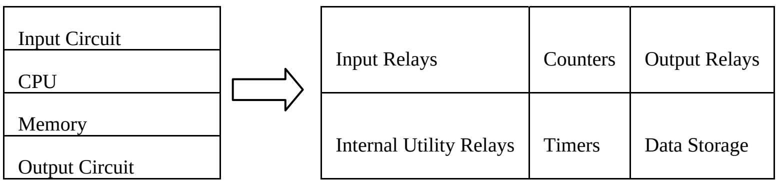


Fig. 19.1 The structure of PLC

What does *each* part do?

INPUT RELAYS-(contacts) These are connected to the outside world. They physically exist and receive signals from switches, sensors, etc.. Typically they are not relays but rather they are transistors**.**

INTERNAL UTILITY RELAYS-(contacts) These do not receive signals from the outside world nor do they physically exist. They are simulated relays and are what enables a PLC to eliminate *external* relays. There are also some special relays that are dedicated to performing only one task. Some are always on while some are always off. Some are on only once during power-on and are typically used for initializing data that was stored.

COUNTERS-These again do not physically exist. They are simulated counters and they can be programmed to count *pulses*. Typically these counters can count up, down or both up and down. Since they are simulated, they are limited in their counting speed. Some manufacturers also include high-speed counters that are hardware based. We can think of these as physically existing. Most times these counters can count up, down or up and down.

TIMERS-These also do not physically exist. They come in many varieties and increments. The most common *type* is an on-delay type. Others include off-delay and both retentive and non-retentive types. Increments vary from 1ms through 1s.

OUTPUT RELAYS-(coils) These are connected to the outside world. They physically exist and send on/off signals to solenoids, lights, etc.. They can be transistors, relays, or triacs depending upon the model chosen.

DATA STORAGE-Typically there are registers assigned to simply store data. They are usually used as temporary *storage* for math or data manipulation. They can also typically be used to store data when power is removed from the PLC. Upon power-up they will still have the same contents as before power was removed. Very convenient and necessary!

A PLC works by continually scanning a program. We can think of this scan cycle as consisting of 3 important steps, as shown in Fig. 19.2. There are typically more than 3 but we can focus on the important parts and not worry about the others. Typically the others are checking the system and updating the current internal counter and timer values.

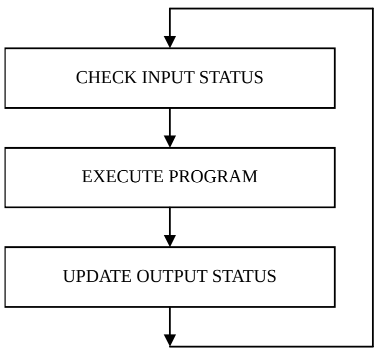


Fig. 19.2　The work process of PLC

Step 1-CHECK INPUT STATUS-First the PLC takes a look at each input to determine if it is on or off. In other words, is the sensor connected to the first input on? How about the second input? How about the third… It records this data into its memory to be used during the next step.

Step 2-EXECUTE PROGRAM-Next the PLC executes your program one instruction at a time. Maybe your program said that if the first input was on then it should turn on the first output. Since it already knows which inputs are on/off from the previous step, it will be able to decide whether the first output should be turned on based on the state of the first input. [3] It will store the execution results for use later during the next step.

Step 3-UPDATE OUTPUT STATUS-Finally the PLC updates the status of the outputs. It updates the outputs *based* on which inputs were on during the first step and the results of executing your program during the second step. Based on the example in step 2 it would now turn on the first output because the first input was on and your program said to turn on the first output when this condition is true.

After the third step the PLC goes back to step one and repeats the steps continuously. One scan time is defined as *the* time it takes to execute the 3 steps listed above. Thus a practical system is controlled to perform specified operations as desired.

New Words and Phrases

1. circuit [ˈsəːkit]	n.	电路，一圈，周游，巡回
2. data storage	n.	数据保存，资料保存
3. dedicated [ˈdedɪkeɪtɪd]	adj.	专注的，献身的
4. execute [ˈeksikjuːt]	vt.	执行，处死，制成，[律]经签名盖章等手续使(证书)生效
5. initial [iˈniʃəl]	adj.	最初的，词首的，初始的
	n.	词首大写字母
6. internal [inˈtəːnl]	adj.	内在的，国内的
7. potential [pəˈtenʃ(ə)l]	adj.	潜在的，可能的，势的，位的
	n.	潜能，潜力，电压
8. pulse [pʌls]	n.	脉搏，脉冲
9. register [ˈredʒistə]	n.	登记，注册，寄存器
	vt.	登记，把……挂号
	vi.	登记，注册
10. retentive [riˈtentiv]	adj.	保持的
11. scan [skæn]	v.	细看，审视，浏览，扫描
	n.	扫描
12. sensor [ˈsensə]	n.	传感器
13. sequential [siˈkwinʃəl]	adj.	连续的，相续的，继续的，有顺序的，结果的
14. specify [ˈspesifai]	vt.	指定，详细说明，列入清单
15. solenoid [ˈsəulinɔid]	n.	[电]螺线管
16. status [ˈsteitəs]	n.	身份，地位，情形，状况
17. switch [switʃ]	n.	开关，电闸，转换
	vt.	转换，转变
18. temporary [ˈtempərəri]	adj.	暂时的，临时的，临时性
19. timer [ˈtaimə]	n.	计时员，记时员，定时器
20. transistor [trænˈzistə]	n.	[电子]晶体管
21. triac [triac]		<美> [电子]三端双向可控硅开关元件
22. via [ˈvaiə]	prep.	经，通过，经由

Notes

[1] A PLC (i.e. Programmable Logic Controller) is a device that was invented to replace the necessary sequential relay circuits for machine control.

PLC(可编程控制器)是为替代实现机器顺序控制所必需的继电器电路而发明的装置。

句中 that 引导的定语从句用来修饰主语 a device，短语 for machine control 用来说明 sequential relay circuits 的作用。

[2] For example, let’s assume that when a switch turns on we want to turn a solenoid on for 5 seconds and then turn it off regardless of how long the switch is on for.

举例，假如我们打开一个开关使一个继电器线圈接通 5 秒钟后断开，并且期间不考虑开关打开了多长时间。

句中 that 引导的从句作谓语动词 assume 的宾语, regardless of 加从句 how long the switch is on for 作状语。

[3] Since it already knows which inputs are on/off from the previous step, it will be able to decide whether the first output should be turned on based on the state of the first input.

因为在前面的步骤中已经知道哪个输入端导通或截止，那么基于第一个输入端的状态可以决定第一个输出是否应被触发。

Since 引导的前半句是一状语从句，which 引导的宾语从句用来作为 knows 的宾语，而后半句中的 whether 引导的也是宾语从句用来作为 decide 的宾语。

Translation skill　It 结构的翻译

在科技文章中经常出现非人称代词 it，其用法并不复杂但非常活跃。有时指代人，有时指代物，有时可与一个分句或一个句子甚至一连串的分句互指。翻译时如果照字翻译成“它”、“它们”、“它的”和“它们的”。有时会使译文意义含糊不清，难以理解。应针对不同的上下文，结合语法结构和专业知识具体分析，采用不同的翻译策略使译文流畅，准确反映原文的含义。

1. 照译成“它”、“它们”、“它的”、“它们的”、“这”

(1) **It** is the only way to keep normal approximation to the binomial.

这是唯一一种保持对于该二项式的正态近似的方法。

(2) A definite disadvantage of glass is that **it** has a much higher density compared to polymeric materials.

玻璃的一项明显缺点在于**它**与聚合材料相比，其密度要大得多。

(3) **It** could run thousands of hours without maintenance.

它不需要维修保养也可以运转几千个小时。

2. 重复译出指代的具体内容

(4) If we compress a gas, **it** becomes hotter.

如果压缩空气，**气体**就热起来。

3. “It”省略不译或译成判断句

(5) **It** appears that the water is broken nowhere by striking against the rocks, and that the descent is perpendicular.

看来水流并未因冲击岩石而发生中断，而是直落下来的。

(6) The use of a telescope makes **it** possible to observe Mars much better.

利用望远镜，能够更好地观察火星。

(7) **It** is his hobby to play football.

踢足球**是**他的爱好。

(8) **It** is generally considered not advisable to criticize your students in public.

公开批评你的学生一般认为**是**不妥当的。

4. 常用的 it 结构的固定译法

英语中有些动词可以用在 It +is (should be，will be, has been) + 动词的过去分词 + that clause 结构中。翻译时，常在动词的前面加上“据……”、“有人……”和“应该……”等词，可用于这类结构的词有 say, know, accept, report, consider, note, stress, believe, feel, learn, find, regard, propose, declare 等词；常用的这类结构有：

It is generally agreed that…(通常认为)

It is accepted that…(可接受的是)

It is usually considered that…(通常认为)

It is felt that…(有人感到)

It is weighted that…(权衡了)

It is understood that…(很清楚)

It is demonstrated that…(已证明，据证实)

It is pointed out that…(有人指出)

It is hypothesized that…(假设)

It has been objected that…(有人反驳)

It is stated that…(据说)

It will be seen from this that…(由此可见，因此)

It is predicted that…(预计)

It is taken that…(人们认为)

例如：

(9) **It should be noted that** if the polarity of point A with respect to N is assumed for the positive half-cycle,…

应该注意，如果把 A 点相对于 N 的极性定为正半周，……

(10) **It is stressed that** the field of science may be divided into two major areas: natural science and social science.

有人强调说，科学领域可分为两大主要领域：自然科学和社会科学。

(11) For a given phase lag θ, **it will be seen that** the data can be fitted with a simple empirical formula of the form.

对于给定的相位滞后θ，**人们将会看出**这些数据能与一个简单的此类经验公式相符合。

(12) **It can not be denied that** TV programmes built children’s knowledge.

不可否认，电视节目增加了孩子们的知识。

it 还可用作 It + is + 形容词 + (for sb 或 sth)+ to 动词不定式；it 还有其他特殊结构，翻译时可将实际的主语译出。如：

(13) Though **it is possible** in principle **to design a fuzzy controller** based on an interpretation of the rules as logical implications, this leads to completely different methods of calculation, …

尽管理论上基于逻辑推理规则的解释**有可能设计出模糊控制器**，但是这会导致出现完全不同的计算方法，……

(14) **It seems clear that** human body is equipped to overlook the need for sleep in order to meet emergencies of quite long duration without doing any harm to it.

似乎很显然，人体能够为应付长时间的紧急事件忽视睡眠的需要，而不损害身体。

(15) **It turned out that** the good Lord had not led him astray.

后来证明，敬爱的上帝并没有使他迷途。

(16) **It is a pity that** you cannot take part in my wedding.

真遗憾，你不能来参加我的婚礼。

(17) **It is** one year **since** we have improved the machine.

我们改进这台机器**已有**一年了。

(18) **It takes** the earth **a whole yea**r **to** travel round the sun once.

地球绕太阳转一圈要**花费一年的时间**。

(19) **It is no time for me to** hide anything.

什么东西都**来不及**藏起来了。

it 还可用作形式宾语，加上形容词作宾语补足语，翻译时可将实际的宾语译出。如：

(20) Heat from the sun **makes it possible for plants to grow**.

来自太阳的热量**使植物的生长成为可能**。

(21) We **find it possible to study English over internet.**

我们发现**通过因特网学英语是可能的**。

(22) The engineer **thinks it feasible that** the machine in the laboratory is introduced in the market

这位工程师认为，在实验室试验的机器投入市场**是可行的**。

it 还可用在强调结构中，也即 It+is(was) +状语+that +句子中，常译作“是……”，“正是……”，“就是……”等；it 用在惯用虚拟条件句中。如：

(23) **Who was it that** you met on the street?

你在街上遇到**的是谁?**

(24) **It was last autumn that** I found the job.

我**是去年秋天**找到这份工作的**。**

(25) **It is my student that (who)** called me this evening.

今晚**是我的学生**给我打的电话。

(26) **It was not until** about 1600 BC when the chariot was invented that the maximum speed was raised to roughly twenty miles per hour.

直到公元前大约 1600 年双轮马拉战车的发明，**才**将最高速度提高到每小时 20 英里。

(27) **It was not until** last year **that** I got the money for the damage.

直到去年我**才**得到损失赔偿。

(28) **It was not until** he came here **that** we began to discuss the plan.

直到他来以后，我们**才**开始讨论这项计划。

(29) **If it were not for** water on the earth , people would thirst to death.

要是地球上**没有**水，人们就会渴死。

(30) **If it had been for the invention of TV set, the world would be in another state.**

要不是发明了电视，世界将会是另一个样子。

Exercises

1. Translate the following into Chinese.

(1) As you can see, the bigger the process the more of a need we have for a PLC. We can simply program the PLC to count its inputs and turn the solenoids on for the specified time.

(2) It can be safely estimated that with a firm understanding of these instructions one can solve more than 80% of the applications in existence.

(3) They physically exist and receive signals from switches, sensors, etc.. Typically they are not relays but rather they are transistors**.**

(4) It is well known that inductors are one of the main building blocks in electronics circuits.

(5) It takes only a small change of base current to control a relatively large collector current.

(6) It is only under near dark conditions that the eye ceases to see color and the world appears entirely in shades of grey.

2. Translate the following into English.

(1) PLC 主要由中央处理器(CPU)、存储器和输入、输出电路构成。我们可以将 PLC 设想为一个装满了成百上千个独立的继电器、计数器、定时器以及数字存储器的盒子。

(2) 该部分也非物理存在。它们是模拟计数器，经编程后可计算脉冲。特别是它们可正计数、倒计数或同时正计数和倒计数。

(3) 例如：在第二步中因为如果第一个输入端被触发，那么你的程序要求第一个输出就应当被触发，当条件为真时，那么第一个输出就应当被触发。

(4) 通信设备把群和超群作为一些单一的单元来传送。对于无线电设备来说，并不需要知道含有多少路。

(5) 当用户外出不在基站服务区域内而无法接受呼叫时，无绳电话系统就可以为这些受距离和移动限制的用户提供服务。

(6) 此体系结构有可能成为多样的媒体服务的主要分布方式。

Reading Material　Automation and Soft PLC

The purpose of automation (in this case automatic control) is to make things better (higher quality), faster (higher efficiency and production rate's), and cheaper than doing it manually. Manual control should be considered as the baseline to compare the advantages of an automated system.

There are a lot of operations that are moving to low labor rate countries that do not use automation. Does this make sense? If you have a very low cost and low quality product then yes, we would think it makes sense. With high cost and high quality products we think that skilled labor and automation make more sense.

Single loop controllers (and their cousins, the special purpose controllers) are great for when you only have one parameter/function/device you need to control. However, we have been in control rooms where there were probably one hundred single loop controllers. Our response was “Wow! You must really like single loop controllers.” The biggest problem with single loop controllers is that once you start to put two or more together, PLCs and other controllers start to make sense, so that the control and monitoring across all functions are integrated.

Even with a PLC or other controller it might be wise to use a single loop or special purpose controller. For example, we have used special purpose/single loop controllers for boilers, heating, compressors, motion control and robotics, welders, E-stops, printers, and other special purpose applications where we wanted to reduce our risk and code development or the company has incredible knowledge and insight on how to control the particular equipment. So don’t lose sight of the fact that single loop and special purpose controllers can be integrated into larger controllers.

We don’t see traditional Programmable Logic Controllers (PLCs) going away. They are built to withstand the factory floor, easily connect to industrial wiring, and are good at real-time control.

There are many new devices that are hard to classify. For example, what is the difference between a “brick” PLC and I/O with an embedded controller? They are not meant to control large processes—just that local group of I/O. For larger applications they would require a higher-level controller to coordinate all of the separate controllers.

For many years, sales people for “soft” PLCs have predicting the doom of traditional PLCs. A soft PLC is a program that runs on an ordinary computer that mimics the operation of a standard PLC. Opponents of soft PLCs point to the “blue screen of death” and other unreliable operations of the PC as the disadvantage. We think that both of these opinions are unfair. Our suggestion is if you know what you are doing then try one of these soft PLCs on a non-critical process first.

In the old days, large “real-time” computers were used in a lot of automation applications. Now that the smaller computers have as much speed, large computers are no longer used.

Today's general purpose computer controllers can be most anything from a PC running Visual Basic or C# to a workstation running proprietary code. Coupled with ordinary networks, computers provide redundancy in that there is one computer per process but the network makes their data available to everyone.

There are lots of "embedded computers" based on PC/104, compact PCI, STD, and other types of computer buses to integrate different modules. There are single task and real-time, multi-tasking operating systems available. These controllers tend to be inexpensive and small in size.

Distributed Control Systems (DCS) are huge mainframe like systems veiled in secrecy so that the company can charge you lots of money upfront for the system and then again every year for the support contracts. They work well－it's all of the extraordinary costs that make them unpopular.

The line between what is a PLC, DCS, computer, I/O, or other controller becomes more blurred every day. Don't get caught up in what you call something－focus on what is best for the application and what the customer is comfortable with.

New Words and Phrases

1.blur [bləː]	n.	模糊，污迹；
	vt.	使模糊不清，玷污
	vi.	变模糊，沾上污迹
2.boiler [ˈbɔilə]	n.	锅炉；用来煮东西的器皿，烧水壶(或锅等)，盛热水器
3.compact [ˈkɔmpækt]	a.	紧密的，小型的，简洁的
	vt.	压紧，使简洁，结实地组成
4.compress [kəmˈpres]	vt.	压缩，归纳
	n.	(消炎等用的)湿敷布，(棉花等的)打包机
5.cousin [ˈkʌzn]	n.	堂(或表)兄弟，堂(或表)姐妹，远亲，同民族而国籍不同的人
6.embed [imˈbed]	vt.	栽种(花等)，埋置，把……嵌进，使深留脑中(或记忆中)
7.incredible [inˈkredəbl]	a.	不能相信的，难以置信的，惊人的，极妙的
8.welder [ˈweldə(r)]	n.	焊工
9.manual [ˈmænjuəl]	a.	手的，手工的，体力的
	n.	手册，简介，键盘，教范
10.mimic [ˈmimik]	vt.	模仿
	n.	能模仿人的动物
	a.	模仿的，假装的
11.module [ˈmɔdjuːl]	n.	模数，[建]预制件，单元，(航天器的)舱

12.monitor [ˈmɔnitə]	n.	班长，告诫物，监听员，监听器
	vt.	监控
	vi.	监听
13.redundancy [riˈdʌndənsi]	n.	过多，冗余，裁员，解雇
14.robotic [rəuˋbɔtik]	a.	机器人的，自动的，像机器人似的，呆板的
15.veil [veil]	n.	面纱，遮蔽物，托词，修女生涯
	vt.	以面纱遮掩

Lesson 20 Microcontroller Integrated Circuit With Read Only Memory

A microcontroller integrated circuit comprises a processor core which exchanges data with at least one data processing and/or storage device. The integrated circuit comprises a mask-programmed read only memory containing a generic program such as a test program which can be executed by the microcontroller. The generic program includes a basic function for writing data into the data processing and/or storage device or devices. The write function is used to load a downloading program. Because a downloading program is not permanently stored in the read only memory, the microcontroller can be tested independently of the application program, and remains standard with regard to the type of memory component with which it can be used in a system. [1]

To be more precise, the invention concerns a microcontroller integrated circuit. A microcontroller is usually a VLSI (Very Large Scale Integration) integrated circuit containing all or most of the components of a "computer". Its function is not predefined but depends on the program that it executes. [2]

A microcontroller necessarily comprises a processor core including a command sequencer (which is a device distributing various control signals to the other components according to the instructions of a program), an arithmetic and logic unit (for processing the data) and registers (which are specialized memory units).

The other components of the “computer” can be either internal or external to the microcontroller, however. In other words, the other components are integrated into either the microcontroller or auxiliary circuits.

These other components of the "computer" are data processing and/or storage devices, for example read only or random access memory containing the program to be executed, clocks and interfaces (serial or parallel).

As a general rule, a system based on a microcontroller therefore comprises a microchip containing the microcontroller, and a plurality of microchips containing the external data processing and/or storage devices which are not integrated into the microcontroller. A microcontroller-based system of this kind comprises, for example, one or more printed circuit boards on which the microcontroller and the other components are mounted.

It is the application program, i.e. the program which is executed by the microcontroller, which determines the overall operation of the microcontroller system. Each application program is therefore specific to a separate application.

In most current applications the application program is too large to be held in the microcontroller and is therefore stored in a memory external to the microcontroller.[3] This program memory, which has only to be read, not written, is generally a reprogrammable read only memory (REPROM).

After the application program has been programmed in memory and then started in order to be executed by the microcontroller, the microcontroller system may not function as expected.

In the least unfavorable situation this is a minor dysfunction of the system and the microcontroller is still able to dialog with a test station via a serial or parallel interface. This test station is then able to determine the nature of the problem and indicate precisely the type of correction (software and/or physical) to be applied to the system for it to operate correctly.

Unfortunately, most dysfunctions of a microcontroller-based system result in a total system lock-up, preventing any dialog with a test station. It is then impossible to determine the type of fault, i.e. whether it is a physical fault (in the microcontroller itself, in an external read only memory, in a peripheral device, on a bus, etc) or a software fault (i.e. an error in the application program) .[4] The troubleshooting technique usually employed in these cases of total lock-up is based on the use of sophisticated test devices requiring the application of probes to the pins of the various integrated circuits of the microcontroller-based system under test.

There are various problems associated with the use of such test devices for troubleshooting a microcontroller-based system. The probes used in these test devices are very fragile, difficult to apply because of the small size of the circuit and their close packing, and may not make good contact with the circuit.

Also, because of their high cost, these test devices are not mass produced. Consequently, faulty microcontroller-based systems cannot be repaired immediately, wherever they happen to be located at the time, but must first be returned to a place where a test device is available. Troubleshooting a microcontroller-based system in this way is time-consuming, irksome and costly.

To avoid the need for direct action on the microcontroller-based system each time the application program executed by the microcontroller of the system is changed, it is standard practice to use a downloadable read only memory to store the application program, a loading program being written into a mask-programmed read only memory of the microcontroller. The mask-programmed read only memory of the microcontroller is integrated into the microcontroller and programmed once and for all during manufacture of the microcontroller.

To change the application program the microcontroller is reset by running the downloading program. This downloading program can then communicate with a workstation connected to the microcontroller by an appropriate transmission line, this workstation containing the new application program to be written into the microcontroller. The downloading program receives the new application program and loads it into a read only memory external to the microcontroller.

Although this solution avoids the need for direct action on the microcontroller-based system (which would entail removing from the system the reprogrammable read only memories containing the application program, writing into these memories the new application program using an appropriate programming device and then replacing them in the system) , it nevertheless has a major drawback, namely specialization of the microcontroller during manufacture.

Each type of reprogrammable memory is associated with a different downloading program because the programming parameters (voltage to be applied, duration for which the voltage is to be applied, etc) vary with the technology employed. The downloading program is written once and for all into the mask-programmed internal memory of the microcontroller and the latter is therefore restricted to using memory components of the type for which this downloading program was written. In other words, the microcontroller is not a standard component and this increases its cost of manufacture.

One object of the invention is to overcome these various drawbacks of the prior art. To be more precise, an object of the invention is to provide a microcontroller circuit which can verify quickly, simply, reliably and at low cost the operation of a system based on the microcontroller.

Another object of the invention is to provide a microcontroller integrated circuit which can accurately locate the defective component or components of a system using the microcontroller in the event of dysfunction of the system.

A further object of the invention is to provide a microcontroller integrated circuit which avoids the need for direct action on the microcontroller-based system to change the application program, whilst remaining standard as regards the type of memory component with which it can be used in a system.

New Words and Phrases

1. auxiliary [ɔːgˈziljəri]	adj.	辅助的
2. drawback [ˈdrɔːˌbæk]	n.	缺点障碍
3. dysfunction [disˈfʌŋkʃən]	n.	官能不良，官能障碍，也作 disfunction
4. interface [ˈintə(ː)ˌfeis]	n.	接口，界面，连接体[装置]
5. irksome [ˈəːksəm]	adj.	令人厌烦的，令人厌倦的，令人恼恨的
6. namely [ˈneimli]	adv.	即，那就是
7. peripheral [pəˈrifərəl]	adj.	次要的，外围的
	n.	外围设备
8. sequencer [ˈsiːkwənsə]	n.	[电脑]程序装置，定序器
9. specialization [ˌspeʃəlaiˈzeiʃən]	n.	特别化，专门化
10. troubleshooting	n.	疑难排解，故障诊断

Notes

[1] Because a downloading program is not permanently stored in the read only memory, the microcontroller can be tested independently of the application program, and remains standard with regard to the type of memory component with which it can be used in a system.

因为装载程序并非永久地存储在只读存储器中，所以可对单片机进行测试，而与应用程序无关，并保持系统中能用的存储器元件为标准类型。

句中的 not 起到否定作用，它的意思是“不”。Not 是全部否定，直接在 be 动词后或引入助动词 do 后加 not 是最简单的否定结构。

[2] Its function is not predefined but depends on the program that it executes.

它的功能不是预先确定的，而是取决于它所执行的程序。

句中的 not…but…的意思是“不是……而是……”，它也是否定结构的一种，否定 not 后的内容，肯定 but 后的内容。

[3] In most current applications the application program is too large to be held in the microcontroller and is therefore stored in a memory external to the microcontroller.

在多数实际应用中，由于应用程序太大，单片机无法存储，因此就存储在单片机的外部存储器中。

句中的 too…to…的意思是“太……而不能……”，注意：它也是否定结构的一种，尽管它里面不含有明显的否定词 no 或 not 等。

[4] It is then impossible to determine the type of fault, i.e. whether it is a physical fault (in the microcontroller itself, in an external read only memory, in a peripheral device, on a bus, etc) or a software fault (i.e. an error in the application program) .

这样就不能确定错误类型是硬件错误(单片机本身、外部只读存储器、外围设备、总线等)还是软件错误(应用程序的错误)。

句中的 impossible 是 possible 加否定前缀 im-而构成的，相应的否定前缀还有 ab-，non-等，此时还需注意某些词没有否定前后缀但仍表示否定意思，例如 doubt，wonder。

Translating Skills　否定结构的翻译

英语中，有些表示否定意义的特殊结构称作否定结构。如果对这些结构不太熟悉，会造成误译甚至错译，翻译时应多加注意。

1. Too…to…“太……不能……”结构的翻译

Too…to 结构常翻译成“太……不能……”；如果 too 前加上 not，never，only，all，but 等词，可译成“并不太……所以能”，表肯定意义；如果在 to 前加 not，表示“太……而不会不”。

(1) She is too young to go to school.

他太小，还不能上学。

(2) What he has promised is too good to be true.

他许的诺太好，恐不可靠。

(3) He is too sad not to hold back tears.

他太悲伤，禁不住流下眼泪。

(4) You know but too well to hold your tongue.

你还是闭嘴的好。

2. Unless 结构的翻译

Unless 句型在大多情况下相当于 if… not 结构，翻译为“要是……就不……”，“除非”等，这时可与 if…not…互换；但在有些虚拟语气的句子中却不能互换。同时还要注意，当用 unless 时，较之用 if…not…态度要明朗，语气更有力。

(5) The supplier is responsible for the performance of all inspection requirements as specified herein, unless otherwise specified in the contract or purchase order.(较之用 if…not…态度要明朗，语气更有力，译作“除非”)

供货方应负责完成本规范规定的全部检验项目，除非在合同或订货单上另有规定。

(6) You will fail in the exam unless you work harder. (可与 if…not…互换，译作“要是……就不……”)

你要是再不努力，就会考不及格了。

(7) Unless bad weather stops me, I go for a walk every day.

除非受阻于坏天气，我每天都出去散步。

(8) I could not expect their help unless they were my friend.(不可与 if…not…互换，在此的意思是指“我不指望他们的帮助，但是如果他们是我的朋友，我会期望他们帮助的”。)

我不能指望他们的帮助，除非他们是我的朋友。

3. Can not… too 结构的翻译

can not…too 结构是固定结构，意指“无论如何……也不过分”，有时 cannot 可用 impossible, difficult 等词去替代；too 可用 enough，difficulty，sufficiently，exaggerate 等替代。其字面意义与实际意义大不相同，翻译时首先熟知其结构，然后正确理解其含义，再根据汉语习惯辨别是否符合语义逻辑，就不会闹出笑话。

(9) You can’t be too careful in exam.

考试时你越仔细越好。

(10) We cannot be too careful in entering into a contract with a businessman.

当与商人订立合同时，你无论如何仔细都不为过。

(11) The importance of this discussion cannot be exaggerated.

这次讨论极为重要。

(12) You cannot take sufficient care in dealing with such a man.

与这样的人打交道，你要格外小心。

4. No … without …结构的翻译

否定词 no，not，never，等和 without 连用时表示语气很强的否定，常译作“一……就……，每……必……，(如果)不/没有……(就)不/没有……”。

(13) Without coke iron cannot be smelt.

没有焦炭就不能炼铁。

(14) No one thinks of China without thinking of the Great Wall.

人们一想到中国就会想到长城。

(15) Neither could theory do without practice, nor could practice do without theory.

理论没有实践不行，实践没有理论也不行。

(16) She never speaks without smiling.

他一说话就先笑。

5. 否定前移结构

由于英汉两种语言的表达习惯的差异，在表达否定意义时，英语往往会有否定转移的情况，而汉语则没有，因此在英译汉时，认真分析句子的逻辑和上下文，掌握常见的否定转移发生的情况，至关重要。常见的转移方式主要有：把否定宾语从句的否定词前移到主句当中；把否定原因状语从句的否定词前移到主句当中；把否定状语的否定词前移到谓语动词前面；把否定主语从句的否定词移到主句当中去。

(17) I don’t think the novel is worth reading.(当主句的谓语动词表示意见、想法、希望、假设等意义时，常把否定宾语从句的否定词转移到主句当中，这类词有 hope，think，believe，imagine，consider，suppose 等)

我认为这本小说不值得一读。

(18) He did not travel by air.(否定介词短语的 not 提到了谓语动词前)

他不是乘飞机去旅游的。

(19) It is not his thought that you should sign the contract with him.(否定真正主语从句的 not 提到了句子的表语前)

他的看法是你根本不应该和他签订协议。

(20) We do not consider melting or boiling to be chemical change.(否定不定式的 not 提到了谓语动词前)

我们认为融化和沸腾不是化学反应。

(21) I didn’t leave college because I was tired of learning. (否定原因状语的 not 放在了谓语动词前，类似的句式有 not…to…，not…as though，not…for…等。但并不是所有的这样的句型都是否定前移，当 as though, because 引导的从句与主句用逗号隔开时，或 because 前有 only，simply 修饰时，不能按否定转移翻译。因此翻译时应根据具体的句内逻辑，具体对待)

我离开了大学，并不是因为我厌倦了学习。

(22) Neutrons carry no charge.(否定谓语的 no 放在了宾语前)

中子不带电荷。

(23) He did not do so well as his classmates.(否定状语的 not 提前放在了谓语动词前)

他不像他的同学干得那样好。

6. No+名词与 not a (an) +名词 结构的翻译

(24) Not every conclusion can hold water. (not every 表部分否定，常译为“不是所有都”，“并非”等)

并非每一结论都站住脚。

(25) He was no singer.(意指“不是的”，表强调)

他决不是歌唱家。

(26) He is not a singer.

他不是歌唱家。

(27) No machine ever runs without some friction.(no 相当于 not a)

从来**没有一台**机器运转时没有摩擦。

7. No more …than 与 not more…than 结构的翻译

no more … than 常译为“两者都不”；not more …than 常译作“不比……更”。如：

(28) He is no more a lawyer than a doctor.

它既不是医生也不是律师。

(29) He is not more careful than you.

他不比你更细心。

8. No more than 与 not more than 结构的翻译

No more than 常译作“只有”，“不过”，“仅仅”；not more than 常译作“不超过”。如；

(30) The coat is no more than $20.

这件大衣只有 20 美元。

(31) The machine imported from Japan is not more than $4000.

这台日本进口的机器不超过 4000 美元。

9. No less than 与 not less than 结构的翻译

no less than 常译作“竟有……之多”，“多达”；not less than 常译作“不少于”，“至少”。

(32) There were no less than two thousand books in his home.

他家里的藏书竟然多达两千本。

(33) There were not less than two thousand books in his home.

他家里的藏书不少于两千本。

10. no better than 与 not better than 结构的翻译

no better than 常译作“和……一样不”；not better than 常译作“并不比……好”，“还不如”。

(34) The computer is no better than that one.

这台电脑和那台差不多。

(35) The computer is not better than that one.

这台电脑并不比那台电脑好。

Exercise

1. Translate the following into Chinese.

(1) I didn't help her because she was rich, or because she was pretty.

(2) No man can have too many friends.

(3) Its significance and importance can never be overemphasized.

2. Translate the following into English.

(1) 我坚持认为，对个人而言，最重要的莫过于这种根植于个人心灵深处的是非感。
(2) 在自然界中不牵涉到两个物体，就不会有作用力。
(3) 引擎并不是因为燃料耗尽停止运转。

Reading Material　Embedded system

In the seventies and eighties of the 20th century, the embedded processor has been used in the fields of industrial control. With the constant growth of the demand for intellectual control of every department, such as industry, health care, and national defence, higher requirements to embedded microprocessor's operation pace, extendible ability, system liability, power consumption and integrated level are needed. In order to meet the needs of various fields, the structure of the embedded microprocessor system has gone through one from CISC to RISC, from 4 bit, 8 bit, 16 bit, 32 bit to 64 bit, can seek address space from 64 KB to more than 16 MB , common encapsulation from 8 feet to 144 feet ,processing speed from 0.1 MIPS to 2000 MIPS. The power consumption of the microprocessor has obvious reduced too, its integrated level is further improved, a large amount of SOC (System on Chip) system emerges.

Today, the embedded system has already been applied to fields such as information household appliances, mobile communication, holding information device and industrial control. Foreign famous processor manufacturers (such as Motorola, Intel, AMD, Hitachi, NSC , EPSON) to introduce each embedded processor one after another, the most representative one is: Motorola company's PowerPC series, Intel company's StrongArm series, AMD company's x86 series , EPSON company's S1C33 series etc. These microprocessors each have their own characteristic, mostly have superior performance, high integrated level, strong extendible ability; they can be applied to all kinds of embedded systems extensively.

An embedded system architecture consists of an application-specific hardware part, which interacts with the environment. At the same time, an application specific software part runs on a microcontroller. The embedded system's final purpose is application. It is based on computer technology, its software and hardware can be disposed and it is an application-specific system which has a strong restrict to the function, cost, volume, power consumption, so the computers used are called the embedded computer. This kind of system is generally made up of embedded microprocessor, peripheral hardware device, embedded operating system and application program so as to control, monitor and manage other device. The structure of the system varies with the application; it can be inlaid and buried in the application device or system in the form of single-board, body of case or distributed joint etc. In essence, the computer in the embedded system is always in a kind of real-time calculation mode, we can think that the embedded computer should have a certain real-time characteristic. In other words, there are some inherent connections between the embedded application and real-time application of the computer, according to the attribute on which the application emphasizes. This kind of computer application system can be called embedded system, real-time system or embedded real-time system.

Most real-time systems are all embedded application. The computer is a kind of intellectual part which install inside of the system which has great response speed, the main function is as the information processing part in a large-scale project system .In this case, users do not need to know that there is existence of the computer in the device, generally ,it can’t be programmed by users. It has some application-specific I/O device and interface. So, the embedded software are developed through cross-develop, development environment is different from real-time environment. Compared with general-purpose computer, the embedded system have many characteristics such as: respond in time, parallel processing, application-specific and compact , skill-intensive, difficult to develop, variety ,etc.

New words and phrases

1. application-specific		adj.	专用的
2. extendible	[ikˈstendəb(ə)l]	adj.	可延长的，可扩张的
3. inlaid	[ˈinˈleid]	adj.	镶嵌的，镶饰的
4. representative	[ˌrepriˈzentətiv]	adj.	代表性的，典型的

Lesson 21 CAD And CAM

The term CAD/CAM is a shortening of Computer-Aided Design (CAD) and Computer-Aided Manufacturing (CAM). Well then, what is a general CAD system?

The general CAD system was developed by considering a wide range of possible uses of such a system. The following were considered in detail:

(1) Mechanical engineering design;

(2) Building design;

(3) Structural engineering design;

(4) Electronic circuit design;

(5) Animation and graphic design.

It was postulated that four basic processes involving graphics occurred, to various degrees, in each field, namely:

(1) Pure analysis - standard design and analysis processes.

(2) Pure draughting–production of a drawing or picture by the manual creation and manipulation of lines, arcs, etc.

(3) Drawing by analysis–the production of a picture or part of a picture directly from analysis: for example, production of cam profiles.

(4) Analysis of drawing–evaluation of the properties of an item described graphically, for example the production of a quantity list by analysis of a builder’s plan drawing.

For the system to be able to support pure analysis it must contain facilities for the running of analysis programs of unlimited length and for the storage and rapid retrieval of large amounts of data.

It was considered important that the user should be able to communicate directly and graphically with analysis programs. Graphics facilities were provided which were considered to be sufficient for a general design draughting system. However, the range of graphical construction techniques is so large in practice that the system contained only as many facilities as could practically be incorporated in the draughting system, leaving other more specialized techniques to be developed by the applications programmer. [1]

For both the production of drawing items by analysis and the analysis of drawings, it is essential that there is a simple efficient link between data produced by the draughting system and analysis programs. It is also essential that graphic data can be annotated in a way which is recognized by analysis programs but which does not affect the draughting system. [2]

It was thought that for most practical application the general draughting system would be incorporated in a much larger specific applications system. For this reason the draughting system was as simple as possible consistent with reasonable running efficiency, so that it could be incorporated into an applications system with the minimum of effort.

The facilities embodied in the general CAD system are now described. These facilities are aimed at allowing a user to input graphical information into the computer and file it. Initial data entry is made by digitizing rough sketches. The system also permits the user to access the data, manipulate it, process it, output it in hard-copy form, or re-file it for permanent storage.

There are many reasons for using CAD; the most potent driving force is competition. In order to win business, companies used CAD to produce better designs more quickly and more cheaply than their competitors. Productivity is much improved by a CAD program enabling you to easily draw polygons, ellipses, multiple parallel lines and multiple parallel curves. Copy, rotate and mirror facilities are also very handy when drawing symmetrical parts. Many hatch patterns are supplied with CAD programs. Filling areas in various colors is a requirement in artwork and presentations. Different style fonts for text are always supplied with any CAD programs. The possibility of importing different graphic file formats and scanning of material (photographs) into a CAD program is also an asset especially as the image can be manipulated, retouched and animated.

Another advantage of a CAD system is its ability to store entities, which are frequently used on drawings. Libraries of regularly used parts can be purchased separately or can be created by the draughtsman. For repetitive use on a drawing, a typical item may be retrieved and positioned in seconds, also oriented at any angle to suit particular circumstances.

Using CAD products, assembly drawings can be constructed by inserting existing component drawings into the assembly drawing and positioning them as required.

Clearance between different components can be measured directly from the drawing, and if required, additional components designed using the assembly as reference.

CAD is very suitable for fast documentation. Previously, engineers and drafters wasted almost 30% of their time looking for drawings and other documents. Editing drawings to effect revisions and produce updated parts lists is quick and easy using a CAD product.

When you’re working on paper and a customer wants to change a drawing, you have to draw it all over again; In CAD, you make the change immediately and print out a new drawing in minutes, or you can transmit it via E-mail or Internet all over the world instantly. On paper creating complex geometry often involves a lot of measuring and location of reference points; In CAD it is a breeze and revisions are even simpler. Many CAD programs include a macro or an add-on programming language that allows customizing it.

Customizing your CAD programs to suit your specific needs and implementing your ideas can make your CAD system different from your rivals. CAD can enable companies to produce better designs that are almost impossible to produce manually and to eliminate dubious options during the conceptual design phase.

Many CAD systems permit the rapid generation of models of proposed designs as wireframes. The solid modeling created in CAD can be transferred to a Finite Element Analysis (FEA) program, which will then verify whether the suggested design will be capable of supporting the expected loads. [3]

CAD will be linked to CAM (Computer Aided Manufacturing) whenever possible.

CAD/CAM systems could produce computerized instructions for computerized machine controllers: lathes, mills, machining centers, turret punches, welding equipment, automated assemblies, etc.

The CAM parts have evolved from the technology of Numerical Controlled (NC) machines. Early NC machines had their own on-board electronic control systems for their servo drives and motors, and where programmed by punched paper tape. In time, that becomes equivalent to a control stream of ASCII text data typed into a text editor.

Each machine maker developed their own control code scheme, usually a very cryptic set of letters for machine actions and numbers for the values of speed, depth, etc., and position coordinates.

NC machines include a computer with a screen and keyboard. These use a “conventional” control language. Modern CAD/CAM systems automatically generate tool paths from a 3D model, and can simulate the cutting action on-screen. The most CAD/CAM systems are modular, that means you can buy whichever modules do the option you want and they integrates into a unified system.

CIM (Computer Integrated Manufacturing) means complete integration of all aspects of manufacturing utilizing computerized information.

CIM is the use of component data created by CAD in the CAM environment. In other words, the part geometry for manufacturing use in computerized form is used for NC programming. This stage of development may be termed small-scale integration.

The most highly developed form of CIM is the creation of a database containing all the information required for flexible manufacturing of components produced by the plant, in a form in which it can be retrieved and used by anyone who needs it. Flexible manufacturing means the ability to make any components in small numbers or well as large, quickly, at economical cost, thus reducing tool charges, work in process and costly inventory.

The main information flows involved in computer integrated manufacturing were clearly outlined by Helberg. CAD generates product model and product describing data that are transformed by CAPP (computer aided process planning) into routings and control programs for the CAM systems. The PPC (production planning and control systems) systems generate and manage all operational data that are used for controlling in the CAM area. CAQ (computer aided quality assurance) on a short-term basis corrects deviations in the manufacturing process and in the long run influences the development of products and methods with regard to quality assurance.

Helberg’s outline does not include further necessary or desirable informational connections between the systems, such as a connection of CAD/CAPP and PPC for an accompanying calculation during design and routing generation, or feedback from manufacturing to planning. Furthermore, at least in the case of single-parts manufacturing, processes like design and process planning can be regarded as elements of the lead time of an order and therefore can be planned and controlled by the PPC system in the same way as the actual manufacturing and assembly processed. [4] In that case a corresponding feedback becomes necessary.

System integration and rationalization is not simply a technological matter, as the CIM theorists suggest. To integrate disperse and incompatible systems we must change traditional procedure, not just throw in more money and equipment. Whenever we try to change procedures we find resistance. The larger the company and the more independent the network, the more difficult it is to turn policies and procedures around. Yet, as Fig. 21.1 suggests, a condition for successful system integration is that it extends along functional and support lines, in the global sense of the distributed environment.

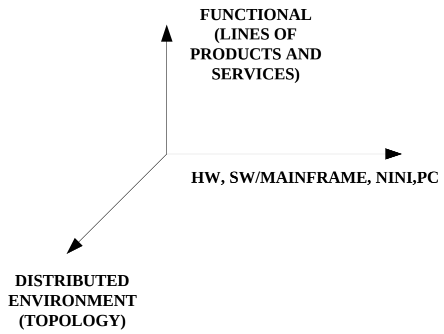


Fig. 21.1 System Integration

Fig. 21.1 System integration should be accomplished along three different axes of reference: distributed environment (topology), functional support, software and hardware.

Because the tangible and intangible benefits of CIM are long term, the usual discounted-cash-flow and return-on-investment methods cannot justify a CIM installation of a flexible manufacturing process frequently. Instead, strategic advantages and intangible benefits must be used to weigh the desirability of investment in CIM.

New Words and Phrases

1. postulate [ˈpɔstjuleit] vt. 要求，假定，以……为出发点
2. manipulation [məˌnipjuˈleiʃən] n. 操作，控制，处理，计算，运算
3. cam [kæm] n. 凸轮，Computer Aided Manufacturing 计算机辅助制造，Computer-Aided Management 计算机辅助管理，Computer-Aided Measurement 计算机辅助测量
4. retrieval [riˈtriːvəl] n. 取回，恢复，修补，重获，挽救，信息检索
5. annotate [ˈænəuteit] vt.,vi. 注解，注释，评注
6. digitize [ˈdidʒitaiz] vt. 将(资料)数字化
7. permanent [ˈpəːmənənt] adj. 永久性的，耐久的，固定不变的
8. potent [ˈpəutənt] adj. 有力的，有效的，有势力的，(议论等)使人心服的

9. polygon [ˈpɔligən]	n.	多边[角]形，封闭折线
10. ellipse [iˈlips]	n.	椭圆，椭圆形
11. symmetrical [siˈmetrik(ə)l]	adj.	对称的，相称的
12. retouch [riːˈtʌtʃ]	vt.	修饰，润色，修改(绘图等)
13. revision [riˈviʒən]	n.	校[修]订，订正，修改[正]
14. breeze [briːz]	n.	微风，煤屑，轻而易举的事，小风波
15. dubious [ˈdjuːbjəs]	adj.	可疑的，不确定的，含糊的， 结果未定的，(工作等)无把握的
16. lathe [leið]	n.	车床
	vt.	用车床加工
17. mill [mil]	n.	磨，磨粉机，铣床，铣刀
18. punch [pʌntʃ]	n.	冲压机，冲床，打孔机
	vt.	冲孔，打孔
19. weld [weld]	vt.	焊接
	n.	焊接，焊缝
20. servo [ˈsəːvəu]	n.	伺服，伺服系统
21. cryptic [ˈkriptik]	adj.	秘密的，含义模糊的，神秘的，隐藏的
22. inventory [ˈinvəntri]	n.	存货，库存量
23. disperse [disˈpəːs]	vt.	疏散，使散开，使分散
24. tangible [ˈtændʒəbl]	adj.	切实的，可触知的，实在的，确实的
25. intangible [inˈtændʒəbl]	adj.	难以明了的，无形的
26. CAPP　computer aided process planning		计算机辅助工艺规划
27. PPC　production planning and control systems		生产计划和控制系统
28. CAQ　computer aided quality assurance		计算机辅助质量保证

Notes

[1] However, the range of graphical construction techniques is so large in practice that the system contained only as many facilities as could practically be incorporated in the draughting system, leaving other more specialized techniques to be developed by the applications programmer.

然而由于实际的制图技术范围太广，作图系统只能尽可能多地将实用工具包含进去，而将其他更专门的技术留给应用程序员去开发。

so large …that 后面是结果状语从句。

[2] It is also essential that graphic data can be annotated in a way which is recognized by analysis programs but which does not affect the draughting system.

另外，图形数据可用能被分析程序识别但不对作图系统产生影响的方法进行注释。

定语从句中两个 which 的功能一样，都用于修饰 in a way.

[3] The solid modeling created in CAD can be transferred to a Finite Element Analysis (FEA) program, which will then verify whether the suggested design will be capable of

supporting the expected loads.

在 CAD 里创建的实体造型可以输入到一个有限元分析(FEA)程序内，以检验设计方案能否承受预期的负荷。

[4] Furthermore, at least in the case of single-parts manufacturing, processes like design and process planning can be regarded as elements of the lead time of an order and therefore can be planned and controlled by the PPC system in the same way as the actual manufacturing and assembly processed. In that case a corresponding feedback becomes necessary.

此外，至少在加工单件零件的情况下，诸如设计和工艺规划这样的过程可以认为是订单交付周期的一部分。因此，它们可以像实际加工和装配过程一样由 PPC 系统规划和控制。在这种情况下，相应的反馈就变得非常必要。

the lead time of an order 可以翻译为“交付周期”。

Translating Skills 词量的增减

英汉两种语言，由于语法结构的差异，修辞手段的不同，表达方式不尽相同，在翻译过程中往往出现词量增加或减少的现象。增词译法就是在原文的基础上添加必要的单词、词组、分句或完整句。这当然不是无中生有地随意增词，而是增加原文中虽无其词但有其意的一些词，从而使得译文在语法、语言形式上符合译文习惯，并在文化背景、词语联想方面与原文一致起来，使得译文与原文在内容和形式等方面对等起来。例如，英语中以 though 引导的让步状语从句，其主句不需要任何呼应词；然而汉语中表示转折的偏正句，偏句里用“虽然”，正句里一般要加上“可是”、“然而”“却”等。汉语不像英语那样大量使用代词，英译汉时往往将代词略去不译。例如, Friction always manifests itself as a force that opposes motion. 句中 itself 的含义应略去不译，否则画蛇添足。全句的译文是：摩擦总是表现为一种对抗运动的力。冠词是汉语中没有的词类，在不少情况下，英译汉时予以省略不译。下面句中出现四个冠词，译文里全部省略，词量减少。*A* transistor is *a* device controlling *the* flow of electricity in *a* circuit**.** 晶体管是控制电路中电流的器件。

词量增加

1. 增加表示名词复数概念的词语

翻译时，有时为了明确原文的含义，需要通过增译“们”、“一些”、“许多”等词语，把英语中表示名词复数的概念译出。例如：

Carbon combines with oxygen to form *carbon oxides.* 碳同氧化合形成多种氧化碳。

Of visible *lights*, red light has the longest and violet the shortest wavelength.在各种可见光中，红光的波长最长，紫光的波长最短。

2. 增加表示事态的词语

汉语的动词没有表示事态的词性变化和相应的助动词，因此翻译时应增译相应的时间副词或助词，用来表示不同的事态。例如：

Contemporary natural science *is* now *working for* new important breakthroughs. 当代自然科学正在酝酿着新的重大突破。

The high-altitude plane *was* and still *is* a remarkable bird.高空飞机过去是而且现在仍然还是一种了不起的飞行器。

3. 增加表示句子主语的词语

当被动句中的谓语是表示“知道”、“了解”、“看见”、“认为”、“发现”、“考虑”等意思的动词时，通常可在其前增加“人们”、“我们”、“有人”等，译成汉语的主动句。例如：

Weak magnetic fields are known to come from the human body.我们知道，人体能产生微弱的磁场。

It is estimated that the new synergy between computers and Net technology will have significant influence on the industry of the future. 有人预测，新的电脑和网络技术的结合将会对未来工业产生巨大的影响。

With the development of modern electrical engineering, power can be transmitted to wherever it is needed. 随着现代化电气工程的发展，人们可以把电力输送到任何所需要的地方。

4. 增加原文中省略的词语

英语句子的某些成分如果已在前面出现，有时则往往省略，在汉译时，一般需要将其补出。例如：

High voltage is necessary for long transmission line while low voltage for safe use . 远距离输电需要高压，安全用电需要低压。

Under no circumstances can more work be got out of a machine than is put into it. 机器输出功决不能大于输入功。

5. 增加具体化、明确化的词语

有些英语句子如果直译成汉语，意思表达不够具体和明确，由此汉译时须增译相关词语。例如：

The statistics brought out a gender division between hard and soft science: girls tending toward *biology*, boys tending *maths and physics.*统计表明，从事硬科学和软科学研究的科学家在性别上存在着差别：女性倾向于生物学的研究，而男性则倾向于数学和物理学的研究。

Were there no electric pressure in a conductor, the *electron flow* would not take place in it. 导体内如果没有电压，便不会产生电子流动现象。

6. 增加起语气连贯作用的词语

为了使译文表达通顺，使词与词、句与句之间前后连贯，有时可增加一些起连贯作用的词，主要是连词、介词和副词。例如：

Using a transformer, power at low voltage can be transformed into power at high voltage .如果使用变压器，低电压的电力就能转换成高电压的电力。

Diskettes that contain a computer virus will spread the virus to the computer. The virus will infect any other diskettes placed in that computer later. Experts say that you should keep your information diskettes write-protected if you can.

带有计算机病毒的软盘会使病毒传到计算机上。而病毒会传到其他任何使用于这台计算机的软盘上。因此专家建议用户最好给自己的信息软盘加上写保护。

7. 增加概括性词语

当句中有几个成分并列时，可根据并列成分数量的多少，增译数、量词表示概括。例如：

The units of “ampere”,” ohm”, and “volt” are named respectively after three scientists. 安培、欧姆、伏特这三个单位是分别根据三位科学家的姓氏而命名的。

The chief effects of electric currents are the magnetic, beating and chemical effects. 电流的主要效应有磁效应、热效应和化学效应三种。

The principal functions that may be performed by vacuum tubes are rectification, amplification, oscillation, modulation and detection. 真空管的五大功能是：整流、放大、振荡、调制和检波。

词量省略

为了更好地表达原意，翻译时往往可以省略原文中某些词语，以便使译文更加严谨、精炼、明确。所省略的词语，在英语中是必不可少的，但译成汉语则显多余。

1. 冠词的省译

一般说来，英语定冠词 the 和不定冠词 a 及 an 在句中用作泛指，常应省略不译，另外，定冠词 the 用作特指，根据汉语表达习惯有时也可省略不译。例如：

Any substance is made of atoms whether it is *a* solid, *a* liquid, or *a* gas.

任何物质，不论它是固体、液体或气体，都是由原子组成。

The direction of *a* force can be represented by *an* arrow.

力的方向可用箭头表示。

2. 代词的省译

英语中的表示泛指的人称代词、用作定语的物主代词、反身代词以及用于比较句中的指示代词汉译时，根据汉语的表达习惯常可省译。另外，有些代词(关系代词)可承前省略。例如：

If *you* know the frequency, *you* can find the wave length. 如果知道频率，就能求出波长。

The difference *between* the two machines consists in power.

这两台机器的差别在于功率不同。

3. 连词的省译

英语中连词使用频率较高，而汉语则不然。因此，翻译时常可省略不译。例如：

Like charges repel each other *while* opposite charges attract.

同性电荷相斥，异性电荷相吸。

If water is cold enough, it changes to ice.水冷却到一定程度便成冰。

The advantage of rolling bearing is *that* they cause less friction.

滚动轴承的优点是它产生的摩擦力较小。

4. 动词的省译

英语谓语必须用动词，汉语不仅可以用动词作谓语，还可以直接用名词、形容词、偏正词组、主谓词组等作谓语。因此，汉译时往往可以省略原文的谓语动词，使译文通顺、简练。例如：

The wire gets hot, for the current *becomes* too great.

电线发热，因为电流太大。

For this reason television signals have a *short* range. (定语“short”转译成汉语的谓语，原文中的谓语“have”无实际词汇意义，省略不译)

因此，电视信号的传播距离很短。

Then *came* the development of the microcomputer.

后来，微型计算机发展起来了。

5. 介词省略

英语中介词使用频率较高，句中词与词之间的关系多用介词来表示，而汉语则不然，主要是通过语序与逻辑关系来表示。因此，翻译时常常可省略不译。例如：

In the transmission of electric power a high voltage is necessary.

远距离输电必须用高压。

In the absence *of* force, a body wi11 either remain *at* rest，or continue to move *with* constant speed *in* a straight line.

倘无外力作用，物体则保持其静止状态，或作匀速直线运动。

6. 引导词的省译

英语中的两个引导词“it”和“there”，翻译时一般省略不译。例如：

It was not until the middle of the 19th century that the blast furnace came into use. (“it”引出强调句)

直到 19 世纪中叶，高炉才开始使用。

There are many kinds of atoms, differing in both mass and properties.

原子种类很多，质量与性质都不相同。

7. 同义词或近义词的省译

英语中有些同义词或近义词往往可以连用，或者表示强调，使意思更加明确；或者表示一个名称的不同说法。在英译汉时，往往省略其中一个词语。例如：

The mechanical energy can be changed back into electrical energy by means of a *generator or dynamo.* 利用发电机可以把机械能转变成电能。

Insulators in reality conduct electricity *but, nevertheless,* their resistance is very high. 绝

缘体实际上也导电，但起电阻很高。

8. 关系代词的省译

Most electricity still comes from fossil fuels, *and so* generates the greenhouse gas, carbon dioxide. 大部分电力仍来自于化石燃料，从而产生了温室气体二氧化碳。

Technology is the application of scientific method and knowledge to industry to satisfy our material *needs* and *wants.*

技术就是在工业上应用科学方法和科学知识以满足我们物质上的需求。

Exercises

1. Translate the following into Chinese.

(1) One difficulty is that almost all of what is called behavioral science continues to trace behavior to states of mind, feelings, traits of character, human nature, and so on.

(2) If the small hot spots look as expected, that will be a triumph for yet another scientific idea, a refinement of the Big Bang called the inflationary universe theory.

(3) I am going to be tested for a driving licence for the fourth time after three times of failures.

(4) Many thanks for your sending next year's catalogue and price list to us.

(5) We are looking forward to your early reply.

(6) I was most upset to learn that Tom kicked his ball through your kitchen window again this morning.

2. Translate the following into English.

(1) 尽管电子计算机有许多优点，但是它们不能进行创造性工作，也不能代替人。

(2) 石油供应可能会随时中断。不管怎样，以目前这种消费速度，只需 30 年左右，所有的油井都会枯竭。

(3) 再者，显而易见的是一个国家的经济实力与其工农业生产效率密切相关，而效率的提高则依赖于各种科技人员的努力。

(4) 在 10 月 9 日的中国日报上看到贵公司招聘土木工程师的广告，于是向您申请这一职位。

(5) 随函寄奉各种货品的样本和最新价目表。

(6) 请给我介绍一下你们系并寄一份入学申请表好吗？

Reading Material Numerical Control

The first NC machines used vacuum tubes, electrical relays, and complicated machine-control interfaces. The second generation of machines utilized improved miniature electronic tubes, and later solid-state circuits. As computer technology improved, NC underwent one of the most rapid changes known in history. The third generation used much-improved integrated circuits. Computer hardware became progressively less expensive and more reliable and NC control builders introduced for the first time Read Only Memory (ROM) technology. CNC was successfully introduced to practically every manufacturing process. Drilling, milling, and turning were performed on “machining centers” and “turning centers”. CNC took over glass cutting, electrical discharge machining, steel-mill roll grinding, coordinate measuring, electrical discharge beam welding, tube bending, drafting, printed circuit manufacturing, coil winding, functional testing, bots, and many other processes.

Along with the many canned cycle options, CNC builders introduced displays for visual editing of part programs in memory. Various in-cycle problems generated alarms and hundreds of diagnostic messages that could be displayed as applicable. Practically every function of the machine was tied into the system and monitored during operation. A constant surface speed control was incorporated and continuously anticipated the most efficient spindle speed for the next cut to minimize time lost for spindle acceleration. The conventional linear and circular interpolations in Cartesian (rectangular) coordinates were supplement by polar coordinates and helical interpolation. Safe zones, which could be set through programmed codes or internal parameters, created an electronic crash barrier to prevent tool collision. The latter group of features marked the arrival of high technology to the manufacturing or metal-cutting industry.

The improvement in drives was as important for the system as the contribution of the microprocessor or the minicomputer. The feed drives, usually known as servo drives, consist of a motor and its control that receives its motion instructions from the CNC. Their performance is essential to the accuracy, reliability, and flexibility of the CNC system.

The fourth-generation microprocessor CNC incorporated in many cases the controversial bubble memory, which are magnetic garnet crystals grown on non-magnetic substrate, ranging in size from 2 to 30 micrometers, and used as nonvolatile data storage. Although at this stage it is not competitive in the large computers, the bubble memory is closing the cost gap with disk storage devices. Insensitive to adverse temperature changes, dust, and vibration, the bubble memory has demonstrated superior reliability in shop environment. However, Hitachi, another electronic giant, believes that bubble memory will provide the economical answer to direct numerical control (DNC) .

Among the strengths of the fourth-generation microprocessor CNC (MCNC) are added part program memory storage, reduction of printed circuit boards, programmable interface, faster memory access, parametric subroutines, and macro capabilities.

The system user can now write specific canned cycles directed to particular application (user macro). Mathematical calculations with do-loop subroutines using variables can now be incorporated in the part program. The microprocessor controls both computations and motion commands. Thus, following an in-process gagging, an out-of-tolerance condition will be fed back and the tool offset will be automatically modified to achieve the desired part dimensions.

New Words and Phrases

1. vacuum [ˈvækjuəm]	n.	(pl. vacuums, -cua [ˈvækjuə]) 真空，真空吸尘器，
	vt., vi.	用真空吸尘器打扫，用真空干燥机干燥
	adj.	真空的
2. undergo [ˌʌndəˈgəu]	vt.	经受；经历；遭受(苦难等)
3. CNC Compute Numerical Control		计算机数值控制
4. diagnostic [ˌdaiəgˈnɔstik]	adj.	诊断的，用于诊断的
5. spindle [ˈspind(ə)l]	n.	(机器的)轴，心轴
6. interpolation [inˌtəːpəuˈleiʃən]	n.	篡改，插补，插入[值]，内插，插值法，内插[推]法
7. Cartesian [kɑːˈtiːzjən]	adj.	笛卡尔的，笛卡尔哲学的
8. rectangular [rekˈtæŋgjulə]	adj.	矩形的，长方形的，直角的
9. coordinate [kəuˈɔːdinit]	n.	同等者，同等物，坐标(用复数)
10. helical [ˈhelikəl]	n.	螺(旋)线，螺旋面
	adj.	螺旋线[纹，面，形]的，螺旋状的
11. barrier [ˈbæriə]	n.	栅栏，屏障，障碍物
12. controversial [ˌkɔntrəˈvəːʃəl]	adj.	争论的，引起争论的，被议论的
13. garnet [ˈgɑːnit]	n.	[船]装货用的滑车，[矿]石榴石，暗[深]红(色)
14. substrate [ˈsʌbstreit]	n.	底层，地层，[无](半导体工艺中的)衬[基]底，基片，垫托物
15. non-volatile [ˈnɔnˈvɔlətail]	adj.	永久的，不挥发的，非挥发性的，非易失性的
16. vibration [vaiˈbreiʃən]	n.	震[颤、振]动，摆动，振荡
17. giant [ˈdʒaiənt]	n.	巨人，大力士，伟人，天才
	adj.	庞大的，巨大的

Lesson 22 Motor Starting and Braking Systems

Motor Starting Systems

Motor starting, particularly for large motors, plays an important role in the efficient operation of electrical machinery. Several different systems are used to start electric motors. The motor starting equipment that is used is placed between the electrical power source and the motor. Electric motors draw a larger current from the power source during starting than during normal operation. [1] Motor starting equipment is often used to reduce starting current to a level that can be handled by the electrical power system.

1. Full-voltage starting

One method of starting electric motors is called full-voltage starting. This method is the least expensive and the simplest to install. Since full power supply voltage is applied to the motor initially, maximum starting torque and minimum acceleration time result. However, the electrical power system must be able to handle the starting current draw by the motor.

Full-voltage starting is illustrated by the diagram of Fig. 22.1. In this motor control circuit, a start-stop pushbutton station is used to control a three-phase motor. When the normally open start pushbutton is pressed, current flows through the relay coil (M) , causing the normally open contacts to close. The line contacts allow full voltage to be applied to the motor when they are closed. When the start pushbutton is released, the relay coil remains energized due to the holding contact. This contact provides a current path from L_1 through the normally closed stop pushbutton, through the holding contact, through the coil (M), through a thermal overload relay, and back to L_2. When the stop pushbutton is pressed, this circuit is opened causing the coil to be deenergized.

2. Primary-resistance starting

Another motor starting method is called primary-resistance starting. This method uses large resistors in series with the power lines to reduce the motor starting current. [2] Often, the resistance connected into the power lines is reduced in steps until full voltage is applied to the motor. Thus starting current is reduced according to the value of the series resistance in power lines since starting torque is reduced according to the magnitude of current flow.

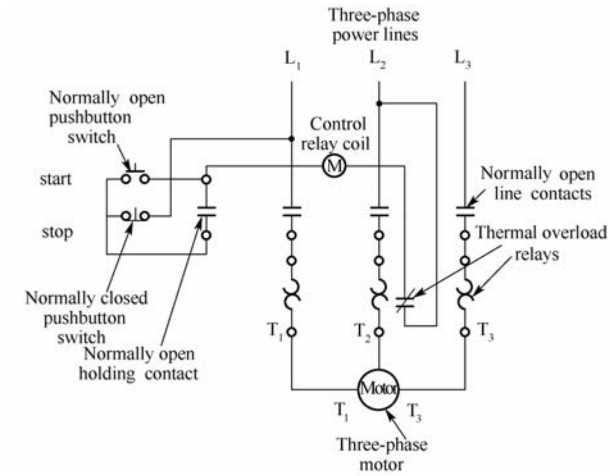


Fig. 22.1 Full-voltage starting circuit for a three-phase motor

Fig. 22.2 shows the primary-resistance starting method used to control a three-phase motor. When the start pushbutton is pressed, coils (S) and (TR) are energized. Initially, the start contacts (S) will close, applying voltage through the primary resistors to the motor. These resistors reduce the value of starting current. Once the time-delay period of the timing relay (TR) has elapsed, contact TR will close. [3] The run contacts (R) will then close and apply full voltage to the motor.

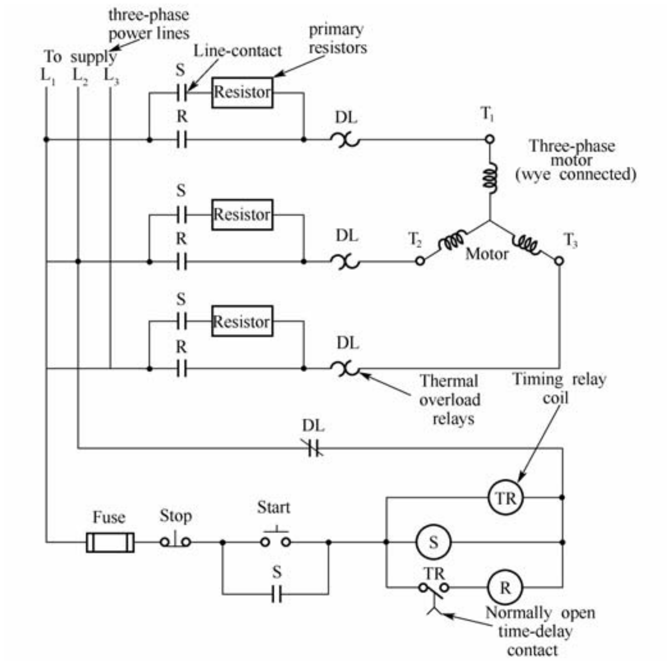


Fig. 22.2 Primary-resistance starter circuit

3. Primary-reactor starting

Another starting method, similar to primary-resistance starting, is the primary-reactor starting method. Reactors (coils) are used in place of resistors since they consume smaller amounts of power from the AC source. Usually, this method is more appropriate for large motor that are rated at over 600V.

4. Autotransformer starting

Autotransformer starting is another method used to start electric motors. This method employs one or more autotransformers to control the voltage that is applied to a motor. The autotransformers used are ordinarily tapped to provide a range of starting-current control. When the motor has accelerated to near its normal operating speed, the autotransformer windings are removed from the circuit. A major disadvantage of this method is the high expense of the autotransformers.

An autotransformer starting circuit is shown in Fig. 22.3. This is an expensive type of control that uses three autotransformers and four relays. When the start pushbutton is pressed, current flows through coils (1S), (2S), and (TR). The 1S and 2S contacts will then close. Voltage is applied through the autotransformer windings to the three-phase motor. One normally closed and one normally open contact are controlled by timing relay TR. When the specified time period has elapsed, the normally closed TR contact will open and the normally open TR contact will close. Coil (R) then energizes, causing the normally open R contacts to close and apply full voltage to the motor. Normally closed R contacts are connected in series with coils (1S), (2S), and (TR) to open their circuits when coil (R) is energized. When the stop pushbutton is pressed, the current to coil (R) is interrupted, thus opening the power-line connections to the motor.

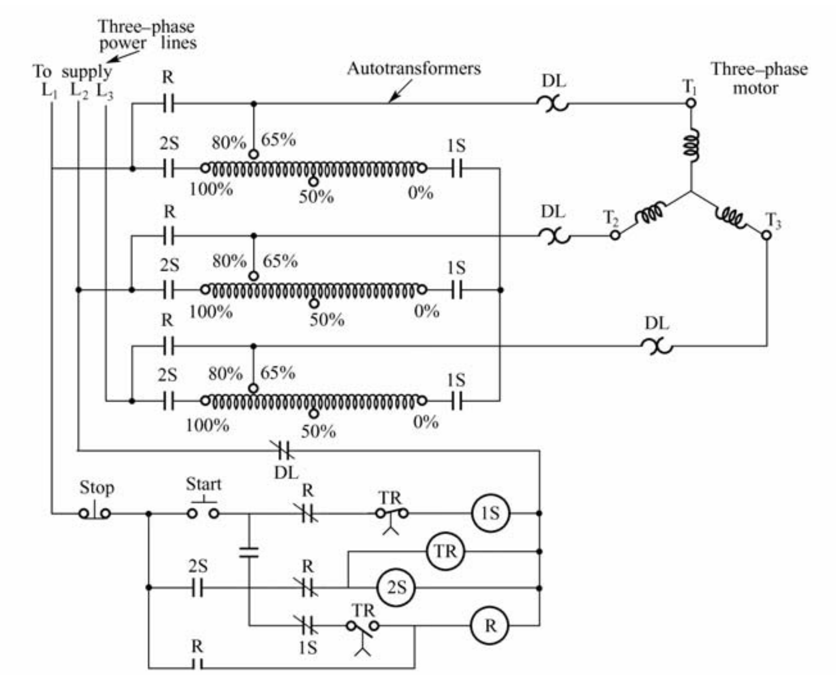


Fig. 22.3 Autotransformer starter circuit with a three-phase motor

Notice that the 65% taps of the autotransformer are used in Fig. 22.3. There are also taps for 50%, 80%, and 100%, to provide more flexibility in reducing the motor-starting current.

5. Wye-delta starting

It is possible to start three-phase motors more economically by using the wye-delta starting method. Since in a wye configuration, line voltage is equal to the phase voltage divided by 1.73($\sqrt{3}$), it is possible to reduce the starting current by using a wye connection rather than a delta connection. [4] This method, shown in Fig. 22.4, employs a switching arrangement which places the motor stator windings in a wye configuration during starting and a delta arrangement for running. In this way, starting current is reduced. Although starting torque is reduced, running torque is still high since full voltage appears across each winding when the motor is connected in a delta configuration.

When the start pushbutton in Fig. 22.4 is pressed, coil (S) is energized. The normally open S contacts then close. This action connects the motor windings in a wye configuration and also activates timing relay (TR) and coil (1M). The normally open 1M contacts then close to apply voltage to the wye-connected motor windings. After the time-delay period has elapsed, the TR contacts change state. Coil (S) deenergizes and coil (2M) energizes. The S contacts which hold the motor windings in a wye arrangement then open. The 2M contacts then close and cause the motor windings to be connected in a delta configuration. The motor will then continue to run with the stator windings connected in a delta arrangement.

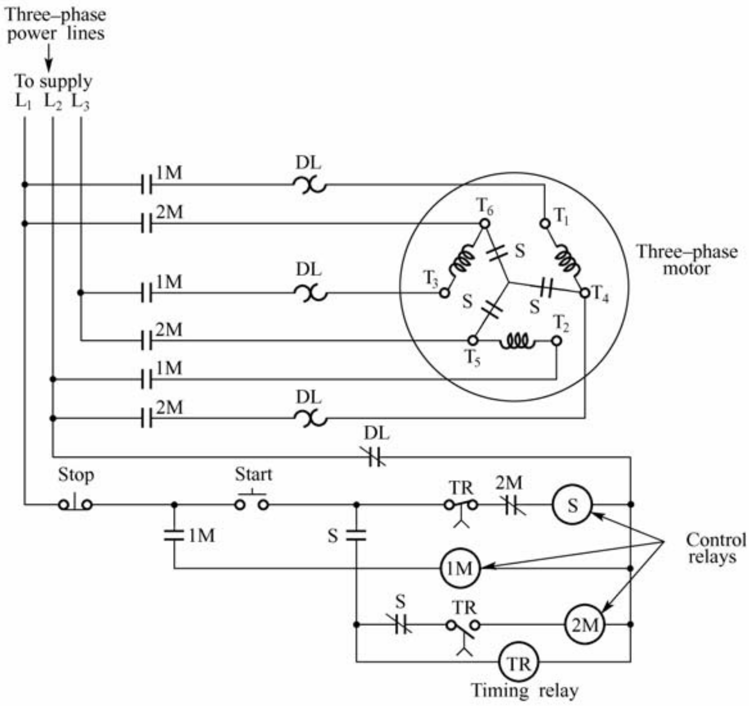


Fig. 22.4 Three-phase wye-delta starting circuit

6. DC Staring systems

Since DC motors have no counter electromotive force (CEMF) when they are not rotating, they have tremendously high staring currents. Therefore, they must use some type of control system to reduce the initial starting current, such as a series resistance. Resistance can be manually or automatically reduced until full voltage is applied. The four types of control systems commonly used with DC motors are ① current limit, ② definite time, ③ CEMF, and ④ variable voltage. The current-limit method allows the starting current to be reduced to a specified level and then advanced to the next resistance step. The definite-time method causes the motor to increase speed in timed intervals with no regard to the amount of armature current or to the speed of the motor. The CEMF method samples the amount of CEMF generated by the armature of the motor to reduce the series resistance accordingly. This method can be used effectively since CEMF is proportional to both the speed and the armature current of a DC motor. The variable-voltage method employs a variable DC power source to apply a reduced voltage to the motor initially and then gradually increase the voltage. No series resistances are needed when the variable-voltage method is used.

Dynamic Braking

When a motor is turned off, its shaft continues to rotate for a short period of time. This continued rotation is undesirable for many applications. Dynamic braking is a method used to bring a motor to a quick stop whenever power is turned off. Motors with wound armatures utilize a resistance connected across the armature as a dynamic braking method. When power is turned off, the resistance is connection across the armature. This causes the armature to act as a loaded generator, making the motor slow down immediately. This dynamic braking method is shown in Fig. 22.5.

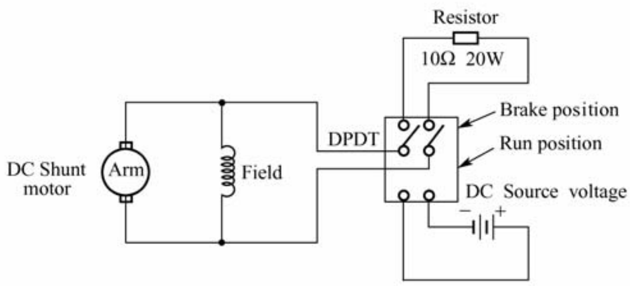


Fig. 22.5　Dynamic braking circuit for a DC shunt motor

Alternating-current induction motors can be slowed down rapidly by placing a “DC” voltage across the winding of the motor. This DC voltage sets up a constant magnetic field which causes the rotor to slow down rapidly. A circuit for the dynamic braking of a single-phase AC induction motor is shown in Fig. 22.6.

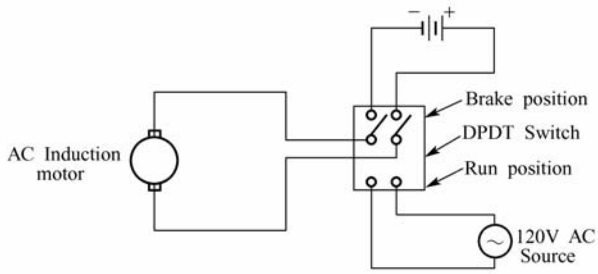


Fig. 22.6 Dynamic braking circuit for a single-phase AC induction motor

New Words and Phrases

1. motor [ˈməutə]	n.	发动机，电动机
2. machinery [məˈʃiːnəri]	n.	[总称]机器，机械
3. equipment [iˈkwipmənt]	n.	装备，设备，器材，装置
4. power source		电源，能源，功率源
5. electrical power system		电力系统
6. maximum [ˈmæksiməm]	n.	最大量，最大限度，极大
	adj.	最高的，最多的，最大极限的
7. minimum [ˈminiməm]	adj.	最小的，最低的
	n.	最小值，最小化
8. illustrate [ˈiləstreit]	vt.	举例说明，图解，加插图于，阐明
	vi.	举例
9. diagram [ˈdaiəgræm]	n.	图表；图解
10. circuit [ˈsəːkit]	n.	电路，回路，网路，线路，一圈，周游，巡回
11. coil [kɔil]	vt. & vi.	盘绕；缠绕；将……卷起
	n.	线圈
12. contact [ˈkɔntækt]	n.	[电]接点；触点；接触通电
	vt.	接触，联系
13. overload [ˈəuvəˈləud]	vt.	使超载，超过负荷
	n.	超载，负荷过多
14. deenergize, -gise [diːˈenədʒaiz]	vt.	去能；去激励；切断，断路；断电，停电，断开
15. resistance [riˈzistəns]	n.	反抗，抵抗，抵抗力，阻力，电阻，阻抗
16. resistor [riˈzistə]	n.	[电]电阻器
17. in series with		与……串联，与……相连
18. current [ˈkʌrənt]	adj.	当前的，通用的，流通的，现在的
	n.	涌流，趋势，电流，水流，气流
19. torque [tɔːk]	n.	扭矩，转矩
20. magnitude [ˈmægnitjuːd]	n.	大小，数量，巨大，广大，量级，量值，幅值

21. timing relay		时间继电器
22. elapse [ɪ'læps]	vi.	(时间)过去，消逝
	v.	流逝
23. reactor [ri(ː)'æktə]	n.	[电]电抗器，电抗(扼流)线圈，电焊阻流圈
24. autotransformer [ˌɔːtəutræns'fɔːmə]	n.	自耦变压器
25. voltage ['vəʊltɪdʒ]	n.	[电工]电压，伏特数
26. winding ['waindiŋ]	n.	绕，缠，绕组，线圈
27. interrupt [ˌintə'rʌpt]	vt.	打断，中断，妨碍，插嘴
	vi.	打断
	n.	(发给电脑的)中断信号
28. flexibility [ˌfleksə'biliti]	n.	弹性，适应性，机动性，挠性
29. wye [wai]	n.	Y 字，Y 字形物
30. delta ['deltə]	n.	(希腊字母)Δ，δ；三角形(物)，(三相电的)Δ 接法
31. configuration [kənˌfigju'reiʃən]	n.	构造，结构，配置，外形
32. phase [feiz]	n.	阶段，状态，相，相位
	v.	定相
33. switch [switʃ]	n.	开关，电闸，转换
	vt.	转换，转变
34. stator ['steitə]	n.	定子，固定片
35. DC (direct current)	n.	[电]直流电
36. CEMF (counter electromotive force)		反电动势
37. armature ['ɑːmətjuə]	n.	盔甲，电枢(电机的部件)，(动植物的防护器官)爪，牙齿
38. sample ['sæmpl]	n.	标本，样品，例子
	vt.	取样，采样，抽取……的样品，试验的一部分，尝试
39. dynamic [dai'næmik]	adj.	动力的，动力学的，动态的
40. breaking ['breikiŋ]	n.	破坏，阻断
41. shaft [ʃɑːft]	n.	轴，杆状物
42. load [ləud]	n.	负荷，重担，负载，加载
	vt.	装载，装填，使担负
	vi.	装货，装弹药，装料
43. generator ['dʒenəreitə]	n.	发电机，发生器，振荡器，加速器
44. AC (alternating current)	n.	交流电
45. magnetic field	n.	磁场

Notes

[1] Electric motors draw a larger current from the power source during starting than during normal operation.

在起动过程中，电机从电源获得的电流要比在正常运行时大得多。

[2] This method uses large resistors in series with the power lines to reduce the motor starting current.

这种方法将大电阻串联在电源线上来减小电机的起动电流。

[3] Once the time-delay period of the timing relay (TR) has elapsed, contact TR will close.

一旦时间继电器 (TR) 的延时时间到了，触点 TR 就会闭合。

[4] Since in a wye configuration, line voltage is equal to the phase voltage divided by 1.73, it is possible to reduce the starting current by using a wye connection rather than a delta connection.

由于 Y(星型)接法中的相电压等于线电压除以 1.73，因此，采用 Y 接法而不是Δ接法可减小起动电流。

Translating Skills　论文的标题与摘要

论文的标题和摘要是信息及成果交流的重要途径，是进行论文检索的有效工具。标题和摘要翻译质量的好坏直接影响着论文的“取舍”、受众范围的大小和信息传递的畅通与否。因此有必要熟知它们的特征，翻译出客观明晰、表述准确、语言精练、符合规范、且能引起读者兴趣的标题和摘要。

科技论文标题的特征及翻译

1. 标题的长度

标题力求重点突出，言简意赅，在整个文章构成中起到画龙点睛的作用。一般在 10 个单词左右，不超过 16 个单词。如果太长可采取增加副标题或标点符号的办法。如：

Low Frequency Wideband SAM
低频带超显微镜

How to Recognize and Translate the Intention of the Source Text
——A Cultural Consideration in Translation
源语意识的识别与翻译——关于翻译的文化因素思考

Substitution: The third function of English Punctuctuation marks
英语标点符号的第 3 种功能：替代功能

2. 标题的书写特征

标题的第一个词(不管实词或虚词)和每一个实词(形容词、副词、名词、动名词)的第一个字母都大写，虚词(介词、连词、冠词等)要小写；也可以所有字母全大写；还可以标题的第一个词的首字母大写，其余单词均小写。如：

REVIEW AND PROSPECT OF COMPUTER CONTROL SYSTEM FOR ALUMIUM SMELTERS IN CHINA

中国铅电解槽计算机控制技术发展的回顾和展望

Review and Prospect of Computer Control System for Aluminum Smelters in China

中国铅电解槽计算机控制技术发展的回顾和展望

On design and realization of the database in the locomotive circuit detector

机车线路检测仪的数据库设计与实现

3. 标题的内容特征

标题中应包含所给出的关键词，能准确反映论文的性质和主要内容，有的还涉及到研究的手段或方法。另外标题的下方应加上作者和作者的单位。

Research on Controllability of Magnetic Suspension with High Temperature Superconducting Electromagnet (标题中的 controllability，magnetic suspension，high temperature superconducting electromagnet 为文中的关键词)

高温超导磁悬浮系统可控性研究(摘自《电气自动化》2005 第 27 卷第 5 期)

标题的语言特征及翻译

1. 标题的常用句式

英语的标题多用动名词、名词短语、介词短语，带疑问词的动词不定式或几种形式混合。汉语经常使用一些词，像“基于……”，“……的设计”，“……的研究”，“……的方法”，“……的设计”，“……的应用”，“……的思考”等，如：

Design of a Simple Wireless Powering System

简易无线电供电系统的设计

An Improved All Digital Phase-locked Loop Design

一种改进的全数字锁相环设计

Chaotic Signal Denoising Based on Threshold Selection of Wavelet Transform

基于小波变换阀值决策的混沌信号去噪研究

On the Misconceptions in Translation Studies and Theories in our country

国内翻译界在翻译研究和翻译理论认识上的误区

2. 标题的修饰语

经常带有前置或后置修饰语，有时前后可同时带有修饰语。可作修饰语的词有冠词、代词、形容词、名词、分词、介词短语等，冠词和不定冠词经常省略，但应注意省略冠词、介词以不影响概念、意义的准确性为原则。如：

Distributed and Cooperative Control for Urban Road Network Traffic

城市路网交通分散协调控制

A Both Matched Dynamic Scheduling Algorithm

一种双匹配动态调度算法

3. 标题的缩略形式

标题可出现专有名词或专有名词的缩略形式。如：

The Study Headway of DTC-PMSM
永磁同步电机直接转矩控制的研究进展

Motorola Motor Controller DSP56F807
Motorola 电机控制器 DSP56F807

4. 标题的专业术语词

标题中的专业术语词的选择。熟悉了科技论文的标题的特点后，在翻译标题时就需要认真研读，准确理解每一个词表达的含义，特别是遇到专业词汇时，更应仔细查找资料或咨询专业人士，选择规范通用的表达法。在准确理解的基础上，找准中心词，理顺主次逻辑关系，根据语法结构恰当地进行翻译。

科技论文摘要的特征及翻译

摘要(abstract)是位于正文之前的一段概括性文字，篇幅较短，层次清楚，字数一般在 200~300 字之间，便于译者翻译，读者查找信息。摘要具有独立性(可独立于论文全文)、概括性(简要概括论文的主要内容)和完整性，好的摘要能让读者不阅读论文的全文就能获得必要的信息，因此常被科技工作者利用。如：

The direct torque control schemes of the permanent magnet synchronous motor (DTC-PMSM) are simply introduced in the paper. And the popular scheme is analyzed detailedly. Also, most improved and researched techniques, including motor speed identification and advanced control algorithm used in DTC-PMSM, are introduced and analyzed recently. The future trend of the DTC-PMSM is also given at last. (摘自《电气自动化》2005 第 27 卷第 5 期)

1. 科技论文摘要的分类及内容特征

摘要的写法分为 3 类。一是指明实质性内容的实验性和技术性较强的论文摘要，称为报道摘要，也称信息型摘要(informative abstract)；二是指明论文主题范围的摘要，称为指示性摘要，也称概括型摘要(indicative abstract)。前者一般要包括研究目的(purpose)、实验方法(method)、结果(数据) (result) 和结论(conclusion) 四要素。其结构严谨，逻辑严密，层次分明，多为理工科的学术论文摘要。后者把重点放在概述论文的论点、分析过程和结论上；三是信息型与概括型的结合。

2. 科技论文摘要的语言特征

1) 时态和语态

在撰写摘要时根据不同的情况可使用不同的时态和语态。当介绍具有普遍事实的背景资料时，多用一般现在时；当概述具有某种研究动向的背景资料时，多用现在完成时。在描述实验目的时，当以 the paper 作主语或出现 In this paper, we…等类似的句式时，常用一般现在时态；当以 The objective of…或 In this study, we…等类似的句式出现时，多用一般过去时。当描述实验方法时多用一般过去时，但当涉及到一些算法、分析方法等时也用一般现在时。

现在科技文摘中为了生动、有力、直接，常使用主动语态。为了客观、强调、简洁也多使用被动语态。具体用什么时态应根据行文的需要，不能过于死板。

This paper presents a new algorithm called both matched algorithm which is suitable to independent job scheduling on heterogeneous processor platforms. (《信息与控制》2005 第 34 卷第 5 期)

本文提出了适于异构环境独立任务调度的双匹配动态调度算法。

Using digital signal processor (DSP), TMS320F240, **we develop** one frequency conversion adjustable-speed system based on FOC principle.(《电气自动化》2005 第 27 卷第 5 期)

以电机控制专用的 DSP 芯片 TMS320F240 为核心，**设计开发了**一套基于矢量控制的变频调速系统。

2) 名词化结构

科技文体摘要要求叙述重点突出，简练客观，信息丰富，逻辑性强，而带有多个修饰语的名词化结构恰好能担此重任，因此科技论文摘要多用名词化结构。

The substitution of the new equipment for the old would result in a considerable increase in production.

新设备替代老设备将会使产量大大增加。

The basic method for **the improvement of soil** is **the application of organic fertilizer.**

改良土壤的基本方法是使用有机肥。

3) 长句

科技论文摘要信息集中，逻辑结构分明，因此大量运用状语和其他修饰成分。如：

Based on analyzing the multiple UCAV mission assignment characteristics, an integer programming based mission assignment method for multiple cooperative UCAVs is proposed.(《信息与控制》2005 第 34 卷第 5 期)

在深入分析多 UCAV 任务分配问题的特点的基础上，提出求解多 UCAV 协同任务分配的整数规划方法。

4) 常用句型的汉英对照：

本文简单介绍了……	…be simply introduced in the paper.
本文研究了……	… be investigated in the paper.
本文研究了……	… be considered.
本文研究了……	… have(has) been studied.
本文介绍了……	This paper introduces…
本文提出了……	…be proposed in the paper.
本文对……进行了评述	…be reviewed.
本文报道了……的方法	…be developed.
本文报道了……的方法	A procedure is described….
本文报道了……的方法	The paper describes….
本文报道了……的方法	… be reported .
本文报道了……的方法	… be described.

Exercises

1. Translate the following into Chinese.

(1) Most types of electrical motors can be made to rotate in either direction by some simple modifications of their winding connections.

(2) The diagram is modified by replacing the shunt field coils with the run windings and the armature with the start windings.

(3) A control circuit for three-phase induction-motor reversing is shown in Figure.

(4) Investigation of PMSM Drive System without Detecting the UVW's Position.

(5) The Application of CAN Bus in the Fuel Cell Car Drive System.

(6) An adaptive Current Controller for Permanent Magnet Synchronous Motor Drivers Based on DSP Technology

2. Translate the following into English.

(1) 小一些的绕组称为串联绕组，因为它与公共绕组串联联接。

(2) 采用能耗制动可以克服电机的惯性，使电机快速停下来。

(3) 利用发电机可将机械能转化为电能。

(4) 本文简单介绍了基于神经网络(neural network)预测控制(predictive control)的基本原理；并且根据神经网络所采用网络模型的不同对预测模型进行了分类以及按照求解最优控制作用方式的不同介绍了几种常用的优化算法。

(5) 本文研究了无 UVW 位置信号检测的永磁同步电机控制方法。电极启动过程分析表明，转子的初始位置确定是问题的关键。本文提出了两种不同负载类型传动系统的电机转子初始位置确定方法，并在一类实际系统中得到实现。结果表明本方法是可行的。

Reading Material　Forward and Reverse Control

Most types of electrical motors can be made to rotate in either direction by some simple modifications of their winding connections. Ordinarily, motors require two magnetic motor contactors to accomplish forward and reverse operation. These contactors are used in conjunction with a set of three-pushbutton switches: forward, reverse, and stop. When the forward pushbutton switch is depressed, the forward contactor is energized. It is deactivated when the stop pushbutton switch is depressed. A similar procedure takes place during reverse operation.

DC motor reversing

Direct-current motors have their direction of rotation reversed by changing either the armature connection or the field connections to the power source. In Fig. 22.7, a DC shunt motor control circuit is shown. When the forward pushbutton is pressed, coil (F) is energized, causing the F contacts to close. The armature circuit is then completed from L_1 through the lower F contact, up through the armature, through the upper F contact, and back to L_2. Pressing the stop pushbutton deenergizes coil (F) .

The direction of rotation of the motor is reversed when the reverse pushbutton is pressed. This is due to the change of the current direction through the armature. Pressing the reverse pushbutton energizes coil (R) and closes the R contact. The armature current path is then from L1 through the upper R contact, down through the armature, through the lower R contact, and back to L2. Pressing the stop button deenergizes coil (R) .

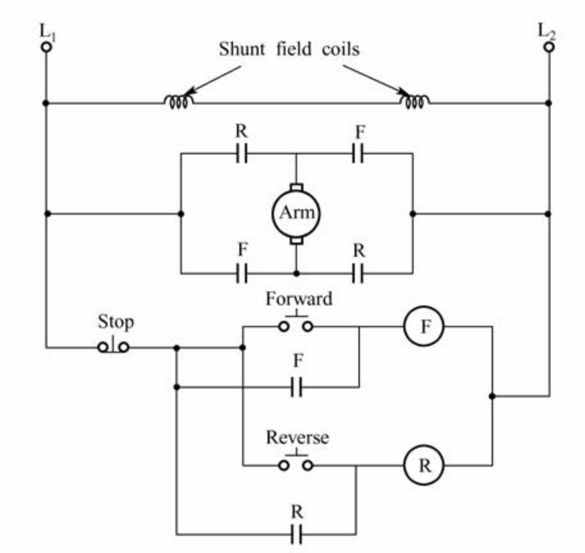


Fig. 22.7　Control circuit for the forward and reverse operation of a DC shunt motor

Single-phase induction-motor reversing

Single-phase AC induction motors that have start and run windings have their direction of rotation reversed by using the circuit in Fig. 22.7. The diagram is modified by replacing the shunt field coils with the run windings and the armature with the start windings. Single-phase induction motors are reversed by changing the connections of either the start windings or the run windings but not both at the same time.

Three-phase induction-motor reversing

Three-phase motors have their direction of rotation reversed by simply changing the connections of any two power lines. This changes the phase sequence applied to the motor. A control circuit for three-phase induction-motor reversing is shown in Fig. 22.8.

When the forward pushbutton is pressed, the forward coil will energize and close the F contacts. The three-phase voltage is applied from L_1 to T_1, L_2 to T_2, and L_3 to T_3 to cause the motor to operate. The stop pushbutton deenergizes the forward coil. When the reverse pushbutton is pressed, the reverse coil is energized and the R contacts will close. The voltage is then applied from L_1 to T_3, L_2 to T_2, and L_3 to T_1. This action reverses the L_1 and L_3 connections to the motor and causes the motor to rotate in the reverse direction.

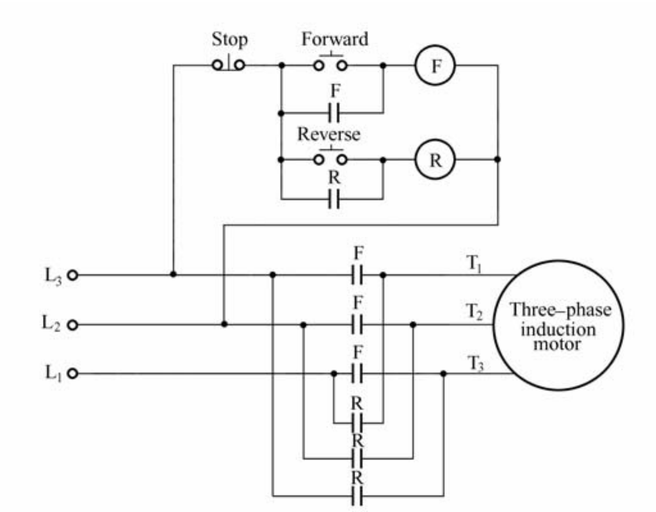


Fig. 22.8 Control circuit for the forward and reverse operation of a three-phase induction motor

New Words and Phrases

1. modification [ˌmɔdifiˈkeiʃən]	n.	更改，修改，修正
2. contactor [ˈkɔntæktə]	n.	[电]接触器，触点，开关；混合器，萃取器
3. conjunction [kənˈdʒʌŋkʃən]	n.	联合，关联，连接词
4. a set of		一组，一套
5. deactivate [diːˈæktiveit]	vt.	解除动员，使无效，复员，使不活动
6. procedure [prəˈsiːdʒə]	n.	程序，步骤，手续；(生产)过程；方法，措施，行动，处置
7. single-phase		单相
8. three-phase		三相
9. phase sequence		相序

Lesson 23 Speed Control of DC Motor

Regulator Systems

A regulator system is one which normally provides output power in its steady-state operation. [1]

For example, a motor speed regulator maintains the motor speed at a constant value despite variations in load torque. [2] Even if the load torque is removed, the motor must provide sufficient torque to overcome the viscous friction effect of the bearings. Other forms of regulator also provide output power; A temperature regulator must maintain the temperature of, say, an oven constant despite the heat loss in the oven. A voltage regulator must also maintain the output voltage constant despite variation in the load current. For any system to provide an output, e.g., speed, temperature, voltage, etc., an error signal must exist under steady-state conditions.

Electrical Braking

In many speed control systems, e.g., rolling mills, mine winders, etc., the load has to be frequently brought to a standstill and reversed. [3] The rate at which the speed reduces following a reduced speed demand is dependent on the stored energy and the braking system used. A small speed control system (sometimes known as a velodyne) can employ mechanical braking, but this is not feasible with large speed controllers since it is difficult and costly to remove the heat generated.

The various methods of electrical braking available are:

(1) Regenerative braking.

(2) Eddy current braking.

(3) Dynamic braking.

(4) Reverse current braking (plugging) .

Regenerative braking is the best method, though not necessarily the most economic. [4] The stored energy in the load is converted into electrical energy by the work motor (acting temporarily as a generator) and is returned to the power supply system. The supply system thus acts as a “sink” into which the unwanted energy is delivered. Providing the supply system has adequate capacity, the consequent rise in terminal voltage will be small during the short periods of regeneration. [5] In the Ward-Leonard method of speed control of DC motors, regenerative braking is inherent, but thyristor drives have to be arranged to invert to regenerate. Induction motor drives can regenerate if the rotor shaft is driven faster than speed of the rotating field. The advent of low-cost variable-frequency supplies from thyristor inverters have brought about considerable changes in the use of induction motors in variable speed drives.

Eddy current braking can be applied to any machine, simply by mounting a copper or aluminium disc on the shaft and rotating it in a magnetic field. The problem of removing the heat generated is severe in large system as the temperature of the shaft, bearings, and motor will be raised if prolonged braking is applied. [6]

In dynamic braking, the stored energy is dissipated in a resistor in the circuit. When applied to small DC machines, the armature supply is disconnected and a resistor is connected across the armature (usually by a relay, contactor, or thyristor) . The field voltage is maintained, and braking is applied down to the lowest speed. Induction motors require a somewhat more complex arrangement, the stator windings being disconnected from the AC supply and reconnected to a DC supply. The electrical energy generated is then dissipated in the rotor circuit. Dynamic braking is applied to many large AC hoist systems where the braking duty is both severe and prolonged.

Any electrical motor can be brought to a standstill by suddenly reconnecting the supply to reverse the direction of rotation (reverse current braking) . Applied under controlled conditions, this method of braking is satisfactory for all drives. Its major disadvantage is that the electrical energy consumed by the machine when braking is equal to the stored energy in the load. This increases the running cost significantly in large drives.

DC Motor Speed Control

The basis of all methods of DC motor speed control is derived from the equations:

$$E \propto \Phi\omega \tag{23-1}$$

$$U = E + I_a R_a \tag{23-2}$$

the terms having their usual meanings. If the I_aR_a drop is small, the equations approximate to

$$U \propto \Phi\omega \tag{23-3}$$

or

$$\omega \propto U/\Phi \tag{23-4}$$

Thus, control of armature voltage and field flux influences the motor speed. To reduce the speed to zero, either U=0 or $\Phi=\infty$. The latter is inadmissible; hence control at low speed is by armature voltage variation. To increase the speed to a high value, either U is made very large or Φ is reduced. The latter is the most practical way and is known as field weakening. Combinations of the two are used where a wide range of speed is required. [7]

A Single-Quadrant Speed Control System Using Thyristors

A single-quadrant thyristor converter system is shown in Fig. 23.1. For the moment the reader should ignore the rectifier BR2 and its associated circuitry (including resistor R in the AC circuit) , since this is needed only as a protective feature and is described in next section.

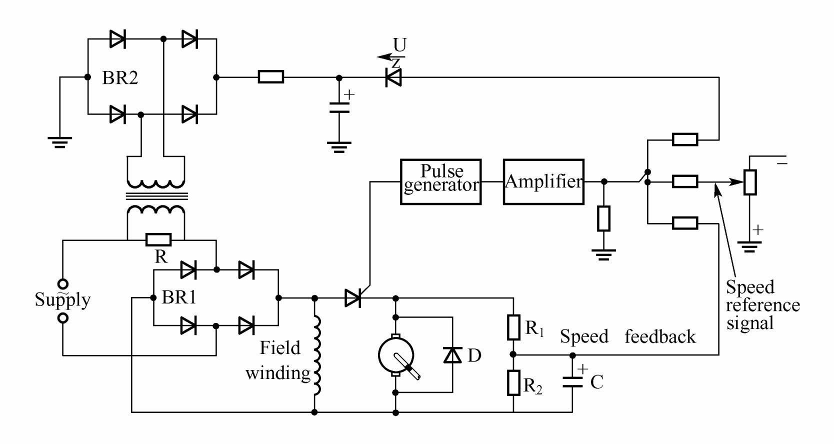


Fig. 23.1　Thyristor speed control system with current limitation on the AC side

Since the circuit is a single-quadrant converter, the speed of the motor shaft (which is the output from the system) can be controlled in one direction of rotation only. Moreover, regenerative braking cannot be applied to the motor; in this type of system, the motor armature can suddenly be brought to rest by dynamic braking (i.e. when the thyristor gate pulses are phased back to 180º, a resister can be connected across the armature by a relay or some other means) .

Rectifier BR1 provides a constant voltage across the shunt field winding, giving a constant field flux. The armature current is controlled by a thyristor which is, in turn, controlled by the pulses applied to its gate. The armature speed increases as the pulses are phased forward (which reduces the delay angle of firing), and the armature speed reduces as the gate pulses are phased back.

The speed reference signal is derived from a manually operated potentiometer (shown at the right-hand side of Fig. 23.1), and the feedback signal or output speed signal is derived from the resistor chain R_1 R_2, which is connected across the armature. (Strictly speaking, the feedback signal in the system in Fig. 23.1 is proportional to the armature voltage, which is proportional to the shaft speed only if the armature resistance drop, I_aR_a, is small. Methods used to compensate for the I_aR_a drop are discussed in Reading Material.) Since the armature voltage is obtained from a thyristor, the voltage consists of a series of pulses; these pulses are smoothed by capacitor C. The speed reference signal is of the opposite polarity to the armature voltage signal to ensure that overall negative feedback is applied.

A feature of DC motor drives is that the load presented to the supply is a mixture of resistance, inductance, and back EMF Diode D in Fig. 23.1 ensures that the thyristor current commutates to zero when its anode potential falls below the potential of the upper armature connection, in the manner outlined before. In the drive shown, the potential of the thyristor cathode is equal to the back EMF of the motor while it is in a blocking state. [8] Conduction can only take place during the time interval when the instantaneous supply voltage is greater than the back EMF. Inspection of Fig. 23.2 shows that when the motor is running, the peak inverse voltage applied to the thyristor is mush greater than the peak forward voltage. By connecting a diode in series with the thyristor, as shown, the reverse blocking capability of the circuit is increased to allow low-voltage thyristors to be used.

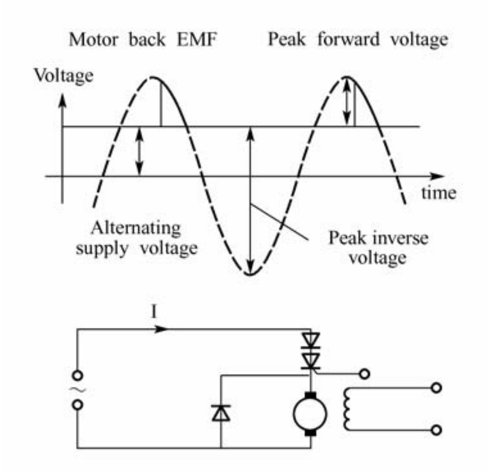


Fig. 23.2 Illustrating the effect of motor back EMF on the peak inverse voltage applied to the thyristor

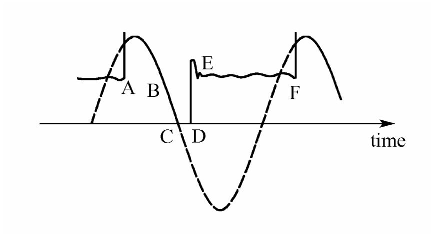


Fig. 23.3 Armature voltage waveforms

The waveforms shown in Fig. 23.2 are idealized waveforms as much as they ignore the effects of armature inductance, commutator ripple, etc. Typical armature voltage waveforms are shown in Fig. 23.3. In this waveform the thyristor is triggered at point A, and conduction continues to point B when the supply voltage falls below the armature back EMF. The effect of armature inductance is to force the thyristor to continue to conduct until point C, when the fly-wheel diode prevents the armature voltage from reversing. When the inductive energy has dissipated (point D) , the armature current is zero and the voltage returns to its normal level, the transients having settled out by point E. The undulations on the waveform between E and F are due to commutator ripple.

New Words and Phrases

1. regulator [ˈregjuleitə]	n.	调整者，校准者，调整器，标准仪
2. steady-state	adj.	不变的，永恒的
3. constant [ˈkɔnstənt]	n.	[数、物]常(系)数，恒(常)量，恒定(不变)值
	adj.	不变的；恒(稳，固，坚)定的；恒久的，经常的，屡见的
4. viscous friction		粘滞摩擦
5. bearing [ˈbɛəriŋ]	n.	轴承，关系，方面，意义，方向，方位
6. oven [ˈʌvən]	n.	烤箱，烤炉，灶
7. rolling mill	n.	轧钢厂

8. mine winder		矿坑卷扬机
9. velodyne [ˈviːləudain]	n.	[电]调速发电机
10. feasible [ˈfiːzəbl]	adj.	可行的；行得通的
11. regenerative [riˈdʒenərətiv]	adj.	再(新)生的，更新的，恢复的；回热(式)的；(正)反馈的，回授的
12. eddy current		涡流，涡电流
13. dynamic [daiˈnæmik]	adj.	动力(学)的，动(态)的，(不断)变化的，电动的，冲击的；有力的，高效能的，生动的
	n.	(原)动力，动态
14. reverse current		反向(反转)电流；往复潮流
15. thyristor [θaiˈristə]	n.	[无]闸流晶体管；半导体开关元件；可控硅；硅可控整流器
16. inverter [inˈvəːtə]	n.	[电]变换器，倒相器；倒换器；反演器；逆变器；变换电路，转换开关；反相旋转换流器；[计]“非”门(电路)，变极器
17. mount [maunt]	n.	乘用马，衬纸，山，装配
	vi.	乘马，爬上，增长
	vt.	爬上，使上马，装上，设置，安放，制作……的标本，上演
18. disc [disk]	n.	圆盘；圆板；唱片；[解]椎间盘；磁盘 (= disk; magnetic disk) ；光盘
19. prolong [prəˈlɔŋ]	vt.	延长，拖延
20. rotor [ˈrəutə]	n.	(电机的)转子；(直升机的)水平旋翼
21. hoist [hɔist]	n.	升起；吊起；推起；起重机
22. flux [flʌks]	n.	涨潮，变迁，[物]流量，通量
	vi.	熔化，流出
	vt.	使熔融，用焊剂处理
23. quadrant [ˈkwɔdrənt]	n.	象限，四分仪；信号区
24. rectifier [ˈrektifaiə]	n.	纠正者，整顿者，校正者，整流器
25. pulse [pʌls]	n.	脉搏，脉冲
26. shunt [ʃʌnt]	n.	转轨；[电]分流
27. potentiometer [pəˌtenʃiˈɔmitə]	n.	[电]电位计，电势计；[信]分压器
28. polarity [pəuˈlæriti]	n.	极性
29. inductance [inˈdʌktəns]	n.	[电]感应；感应器
30. diode [ˈdaiəud]	n.	[电]二极管
31. anode [ˈænəud]	n.	[电]阳极，正极
32. potential [pəˈtenʃ(ə) l]	adj.	潜在的，可能的，势的，位的
	n.	潜能，潜力，电压
33. cathode [ˈkæθəud]	n.	阴极，负极(亦作：negative pole)

34. waveform [ˈweivfɔːm]	n.	波形；信号波形
35. inasmuch [ˌinəzˈmʌtʃ]	adv.	因……之故，因为
36. commutator [ˈkɔmjuteitə]	n.	[电]换向器，整流器
37. ripple [ˈripl]	n.	波纹
	v.	起波纹
38. trigger [ˈtrigə]	vt.	引发，引起，触发
	n.	扳机
39. conduction [kənˈdʌkʃən]	n.	引流；输送，传播；传导，导电；传导性(率)；导热性(率)
40. transient [ˈtrænziənt]	adj.	短暂的，瞬时的
	n.	瞬时现象
41. undulation [ʌndjʊˈleɪʃ(ə)n]	n.	波动，起伏；波状起伏

Notes

[1] A regulator system is one which normally provides output power in its steady-state operation.

调节系统通常是在稳态工作时能提供输出功率的系统。

[2] For example, a motor speed regulator maintains the motor speed at a constant value despite variations in load torque.

例如，电机速度调节器在负载转矩变化时能保持电机转速为恒定值。

[3] In many speed control systems, e.g., rolling mills, mine winders, etc., the load has to be frequently brought to a standstill and reversed.

在许多速度控制系统中，例如轧钢机、矿井提升机等负载要求频繁地停机和反向运转。

[4] Regenerative braking is the best method, though not necessarily the most economic.

反馈制动虽然并不一定是最经济的方式，但却是最好的方式。

[5] Providing the supply system has adequate capacity, the consequent rise in terminal voltage will be small during the short periods of regeneration.

假如供电系统具有足够的容量，在短时间的反馈过程中，端电压相应的升高就很小。

[6] The problem of removing the heat generated is severe in large system as the temperature the shaft, bearings, and motor will be raised if prolonged braking is applied.

在大系统中，散热问题非常重要，因为如果长时间制动，轴、轴承和电机的温度就会升高。

[7] Combinations of the two are used where a wide range of speed is required.

在要求速度调节范围宽的场合可综合使用这两种方法。

[8] In the drive shown, the potential of the thyristor cathode is equal to the back EMF of the motor while it is in a blocking state.

在图示的拖动系统中，当晶闸管处于关断状态时，其阴极电势等于电机的反电动势。

Translating Skills　科技应用文的翻译

广义的科技应用文是指在科技研发、创造、实践过程中及其前后所使用或宣传的文种。包括科技调查报告、科技项目建议书、科技项目可行性报告、科技项目申请书、科技项目计划任务书、科技项目设计说明书、科技实验报告、科技项目进度(进展) 报告、科技项目结题报告、科技成果鉴定书(专家鉴定书)和科技成果报告；科技项目招标书、投标书、中标通知书、技术开发合同；科技成果奖申报书、技术转让合同、咨询和技术服务合同、专利申请书；科技广告、科技简报、科技新闻、科技论文、产品说明书等。科技应用文以应用为目的，具有可操作性，能为科技的推广和发展发挥重要作用。

科技应用文的特征

从上文可以看出科技应用文种类、体式繁多，不同的文献资料其语言也有不同的特点。我们不可能详细论述每一种应用文的翻译，只是就其共同的特点谈谈在翻译时应注意的问题。

(1) 科技应用文的目的明确，功能性强，行文简洁，格式规范。

(2) 科技应用文追求客观、一致、确定性的意义，用词准确，语言明了，表达客观，条理清楚，内容确切。

(3) 科技应用文多使用书面语，严谨朴实，论证有理有据，逻辑性和连贯性强。

(4) 科技应用文多使用专门科技术语和普通科技术语。

(5) 科技应用文多使用长句，句型变化少。

科技应用文翻译

熟悉了科技应用文的文体特征和格式规范后，翻译时还应对原文逐词逐句地仔细研读，结合上下文和文章所涉及的专业知识，对原文进行语法、专业和逻辑分析，透彻理解原文，然后根据汉语的表达习惯组织译文，力求正确表达原文内容，用词准确无误，合乎汉语规范，形式及风格与原文保持一致。

1. 熟悉所译文体的常用句型

招标通告中，其文体极为正式，译文的风格应尽量于原文保持一致，招标通告常会用到下列句型：

单位+ has applied for a loan from +银行 in various currencies toward the cost+项目名称

为……，……从……申请到一笔贷款(以各种货币形式)。

It is intended that part of loan will be applied to…

部分贷款将用于……。

Interested eligible potential bidders may obtain further information and prequalification document from+ 单位 whose addresses are shown below, between + 时刻 and + 时刻 from+ 月日年 to+月日年(except holidays).

凡符合条件自愿投标者，可以按下列地址从……索取详尽资料及资格预审文件。

自……至……，每日……(节假日不休息) 。

在翻译合同时，应熟悉合同的条款、常规格式、一些常用的技术词，规范译文措辞。如：

sole contract	唯一合同
licensed product	许可产品
technical documentation	技术资料
protection of technology	技术保护

Neither party shall terminate this contract without reasonable cause prior to the agreed date of expiration.

双方均不得无故提前终止合同。

申请翻译中常用的表达和句型。

What we claim is...	我们申请的专利是……
We claim...	本专利的权限范围是……
Reference is made to...	请参阅……

2. 熟悉一些科技应用文中常用短语的翻译

如在开发项目意向调查表中的一些表达：

development program nomination form	开发项目提名表
contact address	联系地址
educational record	学历
employment record	工作经历
present position	现行职务
details and duties and responsibilities	承担的职责详情

3. 熟悉国际通用的专业术语

科技应用文中要揭示客观事物的发展规律，传递客观的真理和事实，因此必须使用表意确切的国际通用的专业术语。与此同时科技应用文还使用半专业术语，它们在科技和日常领域中都大量出现，只是有些术语在不同的专业领域中有不同的意义。在翻译时不能望文生义，应注意平时多加积累专业知识，借助专业工具书，必要时咨询专业人士。切忌仅靠主观臆断，如：

Well-**designed** instruments can work for a long time in high temperature.

精心**设计的**仪表能在高温条件下长时间地工作。

In this **design**, the frequency is approximately 370kHz.

在本**电路**中，所用频率大约是 370kHz.

Electrode potential depends on the **Concentration** of the ions.

电极电位决定于离子**浓度**。

A **Concentration** process is important now that the depletion of high grade ores is possibility.

由于目前高质量的矿石可能用完，**富集**过程是重要的。

4. 熟悉长句的翻译

认真分析长句各成分之间的相互关系和意义的主次，准确完整理解句子表达的内容，根据不同的翻译技巧进行合理组织。下面是科技应用文中的两个长句。

Owing to the superiority of cleaning action, in any wash cycle it needn’t use more, as with a suitable measured amount of the power it will serve efficiently and economically.

本品由于洗净力卓越，不必使用多量，适量使用时，既快又省钱。(**分析：**该句的中心句是 it needn’t use more；用分词短语 Owing to the superiority of cleaning action 表明中心句的原因，说明本品的优点；用 as 引导的从句说明本品的另一优点。)

The experiment data of comparing BM with Min-min algorithms show that the running time of BM algorithm is much less than Min-min algorithm and the makespan of BM algorithm is less than Min-min algorithm by 9%.

BM 算法与通常用作评测基准的 Min-min 算法的比较结果表明，BM 算法的运行时间远少于 Min-min 算法，其调度跨度比 Min-min 算法减少约 9%。(**分析**：该句的框架结构为简单句，其中 The experiment data 作整个句子的主语，show 作句子的谓语，that 引导的从句在句中作宾语，从句里有连词 and 连接两个并列分句。其修饰成分有修饰主语的后置定语 of comparing BM with Min-min algorithms；分别修饰从句中两个主语的 of BM algorithm。

表格和各种图表中出现一些本专业的数字符号，需要熟知，具体的在前面的有关章节已经讨论过。

Exercises

1. Translate the following into Chinese.

(1) Before describing the operating of the circuit in detail, it is worthwhile explaining the need to introduce the Ward-Leonard method at a time when thyristor drives are almost universally used.

(2) The AC motor drives the generator at a constant speed, and the armature voltage U is approximately proportional to the generator field flux in accordance with the equations developed earlier.

(3) If any three of the above values are known, then the fourth can be calculated.

(4) Everyone knows that eating too much is bad for you. If you eat a little bit less than you desire, you will live longer. It is also true that if we look across the mammalian kingdom, the short sleepers live longer.

(5) It was necessary that the metal should melt at a low temperature.

(6) Some electrical engineers design and maintain power plants, transmission lines and home and factory electrical installations.

2. Translate the following into English.

(1) 电机控制中常用的电气制动方法有能耗制动、反馈制动、反向制动和涡流制动。

(2) 由于实际电路中的电枢电压是来自晶闸管输出的脉冲信号，因而需要用电容滤波。

(3) 交流异步电机的正反转控制在工程实践中非常常见。
(4) 本发明介绍的是音频信号放大的方法、音频放大电路及其电源。
(5) 卖方应提供三台测量装置。
(6) 申请人必须在本表下面指定位置签名。

Reading Material The Closed-Loop Ward-Leonard Method of Speed Control

Named after its American inverter, the system contains a motor whose speed is to be controlled (known as the work motor) together with a motor generator set. The work motor usually has a constant excitation and its armature is fed by the generator of the motor generator set (the latter operating at constant speed) . The general arrangement is shown in Fig. 23.4.

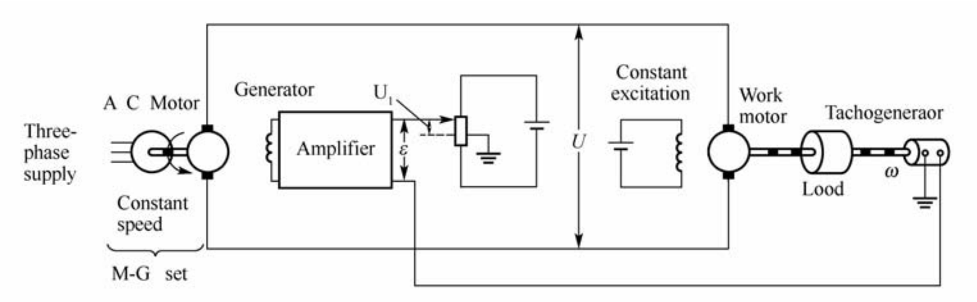


Fig. 23.4 Closed-loop Ward-leonard speed control system

Before describing the operating of the circuit in detail, it is worth while explaining the need to introduce the Ward-Leonard method at a time when thyristor drives are almost universally used. The Ward-Leonard method of speed control allows the user to smoothly control the speed of the work motor from standstill to full speed in either direction of rotation. Moreover, regenerative braking is inherent for both directions of drive, so that electrical braking is available from full speed in either direction of rotation down to “creep” speed (the work motor must finally be stopped by some of mechanical braking) . That is, the Ward-Leonard method of speed control is the forerunner of an ideal four-quadrant thyristor drive, and serves as an excellent model of speed control.

The AC motor drives the generator at a constant speed, and the armature voltage U is approximately proportional to the generator field flux in accordance with the equations developed earlier. The flux, in turn, is dependent on the error voltage at the amplifier terminals. To a first approximation, neglecting the effects of loading and saturation, $U \propto \varepsilon$. Since the work motor excitation is constant, its flux is constant and

$$\omega \propto U \tag{23-5}$$

Combining the above equations shows that

$$\omega \propto \varepsilon \tag{23-6}$$

i.e., the system is error-actuated and the work motor shaft speed is proportional to the error voltage.

The direction of rotation of the work motor shaft is reversed by reversing the polarity of the speed reference voltage U_1. This reverses the polarity of the generated voltage and current, reversing the work motor torque.

In Fig. 23.4, the speed is measured by a tachogenerator, but from Eq.(23-5) the armature voltage could be used as the speed signal, providing that the load current is small. With a large value of load current, the I_aR_a drop makes Eq.(23-5) inaccurate. For accurate speed control, the voltage fed back must be proportional to the motor back EMF $E=(U-I_aR_a)$. A simple circuit which compensates for the armature voltage drop is shown in Fig. 23.5. The PD across R is I_aR_a, and the voltage at B relative to A is $[R_2U/(R_1+R_2)-I_aR]$, which is of similar from to the equation for the back EMF. By a suitable choice of values, the voltage between A and B is proportional to the back EMF, eliminating the need for a tachogenerator. In practice, the resistor R is not always necessary, as the PD across the interpoles of the work motor may be utilized.

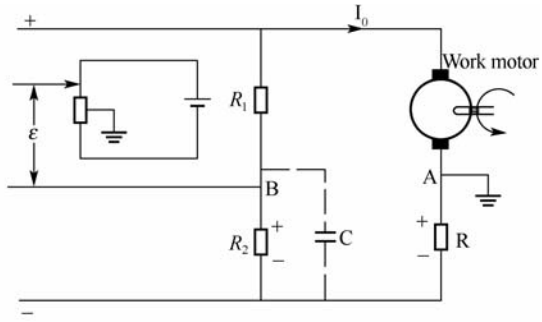


Fig. 23.5　Armature voltage drop compensation

It can be shown that, for a motor of armature resistance Ra, which is used in a circuit of the type in Fig. 23.5, I_aR_a drop compensation is obtained if

$$R_1R=R_2R_a \tag{23-7}$$

If any three of the above values are known, then the fourth can be calculated.

While the circuit in Fig. 23.5 is satisfactory for Ward-Leonard type drives in which the work motor armature voltage is supplied by a DC generator, it may be unsuitable for a thyristor drive (see, for example, the speed control system in Fig. 23.1) in which the armature supply is obtained from a thyristor. The reason is that the output from a thyristor supply is rich in harmonics, and even when the condition in Eq. (23-7) is satisfied, the voltage between point A and point B in Fig. 23.5 is very distorted, even when the work motor is running at constant speed. To reduce the harmonics in the voltage between A and B, it is necessary to shunt resistor R_2 by capacitor C, as shown by the dotted connection in Fig. 23.5. The value of capacitor C can be calculated from the equation.

$$C=L/(R_1R) \tag{23-8}$$

where L is the inductance of the work motor armature. In a thyristor drive, Eq.(23-7) and (23-8) must be satisfied to give I_aR_a compensation.

The work motor may be directly coupled to the drive as shown in Fig. 23.4, particularly in large low-speed installations, or it may be coupled through a speed-reducing gearbox, so permitting a high-speed low-inertia motor to be used. If a very wide speed range is required, the basic system is modified to allow field weakening of the work motor to give the higher values of speed. This technique is employed in many machine tool applications.

A feature of the Ward-Leonard system is that regenerative braking is inherent. When the reference signal is reduced, the generator voltage falls, but the work motor speed (and back EMF) is maintained for a short time by the stored energy in the load. Momentarily, the work motor back EMF is greater than the generator voltage and the direction of the current through the two DC machine armatures reverses, causing the work motor to function as a generator (driven by the stored energy of the load) . The DC generator now operates as a motor, forcing the AC motor to operate as a generator returning energy to the power supply system. Regenerative braking down to the work motor "creep" speed is obtained in this way.

New Words and Phrases

1. set [set]	v.	放，置，移动到，使(人或事物处于某种状态)，提出，树立，规定，调整
	n.	一套，一副，一批，接受机，装置，趋势，布景
	adj.	固定的，规定的，坚决的，固执的，事先做好的
2. excitation [ˌeksi'teiʃən]	n.	刺激，兴奋，扰(激)动，干扰；激发；激励，励磁，
3. universally [juːnɪ'vɜːsəlɪ]	adv.	普遍地，全体地，到处
4. inherent [in'hiərənt]	adj.	固有的，内在的，与生俱来的
5. creep [kriːp]	vi. & n.	爬行，蠕动；蠕变(升)，(材料)潜伸，潜移，塑性变形；(频率)漂移，滞缓；渗(水)，漏电
6. forerunner ['fɔːˌrʌnə]	n.	先驱(者)，传令官，预兆
7. terminal ['təːminl]	n.	终点站，终端，接线端
	adj.	末期，每期的，每学期的
8. tachogenerator ['tækə'dʒenəreitə]	n.	测速发电机，转速表传感器
9. interpole ['intə(ː) pəul]	n.	极间极，附加极，辅助整流极，换向极
10. capacitor [kə'pæsɪtə(r)]	n.	电容器
11. installation [ɪnstə'leɪʃ(ə) n]	n.	就职，装设，安置；装置物
12. gearbox ['giəbɔks]	n.	齿轮箱，变速箱，传动箱；进刀箱，进给箱；减速器

Lesson 24 Frequency Control for AC Motor

Adjustable-Frequency Concepts

Let's review for a moment the concepts of line and forced commutation as they are used to obtain adjustable frequency to be applied to an AC squirrel cage induction motor. Fig. 24.1 illustrates what the controller is supposed to do: create an adjustable voltage and adjustable frequency from fixed line voltage and fixed line frequency. Let's first decide what we need to put in the box. The circuit using six thyristors will not work. It can create an adjustable voltage to the motor, but the line frequency passes straight on through. Therefore, we need a means of creating an adjustable frequency as well as an adjustable voltage. [1] The simplest way of doing this is by means of a "DC link". The DC link is then controlled by one of several means to create the adjustable frequency. In some cases the DC link is also controlled to create the adjustable voltage. To form the DC link, the incoming AC voltage must somehow be changed to a DC voltage, after which the DC is changed back to AC for applying to the AC motor. [2]

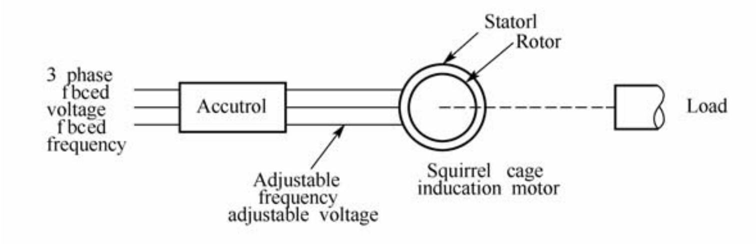


Fig. 24.1 Conversion functions of adjustable-frequency controllers applied to AC motors

Fig. 24.2 shows a generalized frequency controller with a DC link. The input uses six semiconductors to provide the DC, and the output uses six semiconductors to provide the adjustable frequency. [3] Which type of semiconductor should be selected for each box? Since the AC line is always connected to the first box, the input devices can be line commutated. They can therefore be diodes, thyristors, GTOs, transistors, or triacs. GTOs are quite costly, and transistors and triacs may not have the desired ampere capacity and voltage capabilities. Therefore, the input power devices will be diodes or thyristors or perhaps a combination.

Again the devices in the output box of Fig. 24.2 must utilize forced commutation because there is no natural or line means to turn off the power semiconductors. This means that they must be thyristors, transistors, or GTOs. Triacs could be used but are limited in capacity.

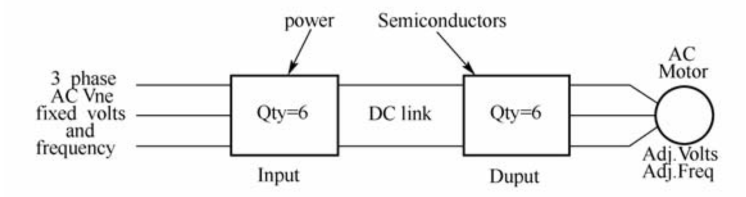


Fig. 24.2 Generalized adjustable-frequency controller with DC link

Let's start with diodes in the input box. With diodes, there is no means of adjusting the DC link voltage. Therefore, both the adjustable frequency and the adjustable voltage must be created in the output stage. This is actually done in the real case. The resulting system is called pulse-width modulation (PWM).

If the input box were to use thyristors instead of diodes, they can be controlled to provide adjustable DC link voltage. [4] The output stage then needs only to create the adjustable frequency from the DC link and pass the adjustable voltage on through to the AC motor, together with the adjustable frequency. The output stage can therefore be less complex than a PWM system, but the input stage must be more complex. However, this method is also in popular use for frequency controllers, in one of two arrangements. One is known as the adjustable voltage inverter (AVI) . The other is known as the current source inverter (CSI) .

Table 24−1 is a summary of power devices as used in these three most common types of frequency controllers.

Table 24−1 Summary of Power Semiconductors as Used with the Three Basic Types of Adjustable-Frequency Controllers

Type of controller	Input devices	DC link voltage	Output devices
PWM	Diodes	Constant	Thyristors
AVI	Thyristors	Adjustable	Diodes
CSI	Thyristors	Adjustable	***GTOs***

Terminology

Let's review for a moment some of the various terms as they are used to describe solid-state frequency controllers. There are rigid technical definitions as well as generally used terminology. First, the technical definitions as suggested by organizations such as IEC, NEMA, and IEEE (Institute of Electrical and Electronics Engineers): [5]

(1) Converter: an operative unit for electronic power conversion comprising one or more valve devices (power semiconductors, for example).

(2) Self-commutated converter: a converter in which the commutation voltages are supplied by components within the converters.

(3) Rectifier: a converter for conversion from AC to DC.

(4) Inverter: a converter for conversion from DC to AC.

(5) Indirect AC converter: a converter comprising a rectifier and an inverter with a DC link.

If we look at Fig. 24.2, all definitions above apply to solid-state frequency controllers in one form or another, and definition 5 covers the complete system. However, general usage in the United States is to call the configuration of Fig. 24.2 an “inverter”: PWM inverter, adjustable voltage inverter, or current source inverter [also called an adjustable-current inverter (ACI)].

For the rest of this lesson we use the terms “adjustable-frequency controller” and “inverter” interchangeably, recognizing, of course, that we can have the whistle blown on us at any time for not using correct technical terminology.

PWM Versus AVI Versus CSI

All three of the most commonly used adjustable-frequency controllers consist of three basic sections, as shown in Fig. 24.2. The input section converts the incoming AC power to DC. The center section, or DC link, smoothes out or filters the DC voltage. The output section inverts the DC into AC of the desired frequency.

The differences among these three types of controllers are (a) the manner in which the adjustable voltage is obtained, and (b) the technique used to create the adjustable frequency.

PWM

Pulse-width modulation (PWM) utilizes diodes in the input stage to provide a fixed-voltage DC bus. The output, or inverter stage, creates a series of pulses of constant voltage with the pulse widths and pulse quantities varying as required by the desired output frequency and voltage. The output section supplies and controls both parameters, adjustable frequency and adjustable voltage.

AVI

Adjustable-voltage inverters (AVIs) use thyristors in the input stage to obtain adjustable voltage in the DC link. The output stage switches this DC voltage with thyristors or transistors or GTOs to obtain a square-wave voltage whose width and timing sequence are proportional to the desired frequency. Voltage control is obtained in the first stage. Frequency control is obtained in the second stage.

CSI

Current source inverters (CSIs) are similar to AVIs, except that the control is arranged to provide a series of square waves of current output. [6]

Comparison of PWM, AVI, and CSI.

Fig. 24.3 shows the three types of adjustable-frequency controllers, with power circuits and resulting theoretical output voltage and current waveforms. There are numerous variations within these three basic systems, such as sine-wave modulation with PWM, chopper techniques, and output circuitry that provides a form of load commutation. These refinements are beyond the scope of this lesson and are covered in the references. [7]

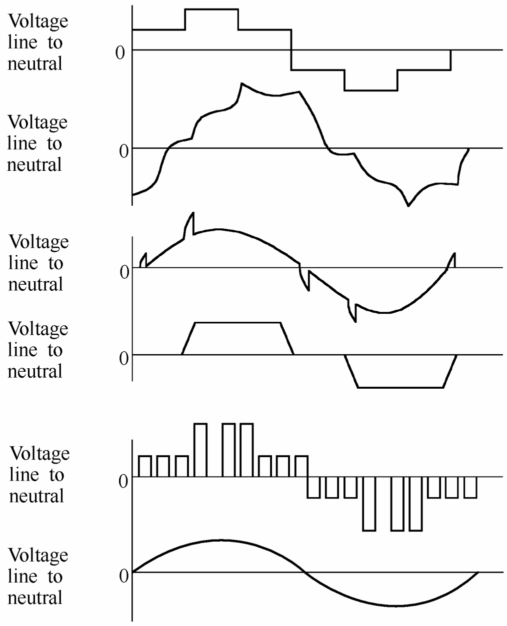


Fig.24. 3 Power circuit and output waveforms of basic types of adjustable-frequency controllers

New Words and Phrases

1. review [ri'vjuː]	vt.	回顾，复习
	n.	回顾，复习，评论
2. concept ['kɔnsept]	n.	观念，概念
3. squirrel ['skwirəl]	n.	松鼠
	v.	储藏
4. induction [in'dʌkʃən]	n.	引入(导)，诱导(作用)；感应(现象)，电感，磁感；归纳(法，推理)
5. link [liŋk]	n.	链环，连结物，火把，链接
	vt.	连结，联合，挽
	vi.	连接起来
6. kink [kiŋk]	n.	(管子、头发等的)纽结，纠缠；怪念头；乖僻，古怪
7. generalize ['dʒenərəlaiz]	vt.	归纳，概括，推广，普及
8. semiconductor ['semikən'dʌktə]	n.	[物]半导体
9. transistor [træn'zistə]	n.	[电子]晶体管
10. ampere ['æmpeə(r) ; (*US*) 'æmpɪər]	n.	安培
11. capacity [kə'pæsiti]	n.	容量，生产量，容量，智能，才能，能力，接受力，地位

12. capability [ˌkeipəˈbiliti]	n.	(实际)能力，性能，容量，接受力
13. width [widθ]	n.	宽度，广阔，幅员(度)，阔； [计]位数；幅，一块料子
14. modulation [ˌmɔdjuˈleiʃən]	n.	调节；调谐，调制
15. arrangement [əˈreindʒmənt]	n.	排列，安排；协调；调解；改编乐曲； 改编的乐曲
16. solid-state	adj.	固态的
17. definition [ˌdefiˈniʃən]	n.	定义，解说，精确度， (轮廓影像等的)清晰度
18. terminology [ˌtəːmiˈnɔlədʒi]	n. –gies	术语；专门名词
19. operative [ˈɔpərətiv, ˈɔpəreitiv]	adj.	运转着的，有效验的，手术的，实施的
20. unit [5ju:nIt]	n.	个体，(计量)单位，(军队的)部队单位， [数学]最小的整数
21. interchangeably	adv.	可交地，可替交地
22. whistle [(h) wisl]	n.	口哨，汽笛，口哨声，汽笛声
	v.	吹口哨，鸣汽笛
23. versus [ˈvəːsəs]	prep.	对(指诉讼，比赛等中)，与……相对
24. filter [ˈfiltə]	n.	滤波器，过滤器，滤光器
	vt.	过滤，渗透
	vi.	滤过，渗入，(消息等)走漏
25. bus [bʌs]	n.	公共汽车；公共马车； [电]汇流条，母线，总线
26. parameter [pəˈræmitə]	n.	[数]参数(量，项，词)；变数特性； 补助变数
27. timing sequence		时序
28. comparison [kəmˈpærisn]	n.	比较，对照，比喻，比较关系
29. sine-wave	n.	(三角的)正弦波
30. chopper [ˈtʃɔpə]	n.	砍伐者(物等)；切碎机；断路器， 限制器，斩波器，交流变换器

Notes

[1] Therefore, we need a means of creating an adjustable frequency as well as an adjustable voltage.

因此，我们需要产生可调电压和可调频率的方法。

[2] To form the DC link, the incoming AC voltage must somehow be changed to a DC voltage, after which the DC is changed back to AC for applying to the AC motor.

为了构成直流环，输入的交流电压必须通过某种方式变成直流电压，再由直流变成交流加到交流电机上。

[3] The input uses six semiconductors to provide the DC, and the output uses six

semiconductors to provide the adjustable frequency.

输入端使用 6 个半导体元件提供直流电，输出端使用 6 个半导体元件提供可调频率。

[4] If the input box were to use thyristors instead of diodes, they can be controlled to provide adjustable DC 1ink voltage.

如果输入框采用晶闸管而不是二极管，就可以通过控制晶闸管来提供可变的直流环节电压了。

[5] IEC =International Electrotechnical Commission 国际电工技术委员会；
International Electrochemical Commission 国际电化学委员会；
International Electric Corporation 国际电气公司 [美]；
Industrial and Engineering Chemistry 《工业与工程化学》([美]期刊名)；
Interstate Engineering Corporation 州际工程公司 [美]；
Ion Exchange Chromatography 离子交换色谱法

NEMA = National Electrical Manufacturers Association 美国电气制造者协会；
National Electric Motor Association 全国电动机协会[美]；
National Electronic Manufacturing Association 国家电子制造协会

IEEE = Institute for Electrical and Electronic Engineers 电气和电子工程师学会[美]

[6] Current source inverters (CSIs) are similar to AVIs, except that the control is arranged to provide a series of square waves of current output.

电流型逆变器与电压型逆变器相似，区别在于通过它的控制可提供连续的电流输出方波。

[7] These refinements are beyond the scope of this lesson and are covered in the references.

这些改进电路超出了本课的范围，具体论述见参考文献。

Application Skills 英文书信的写作基础

当今随着各类组织、团体或个人对外交流的日益频繁，人们使用英文书信的范围和机会越来越多。学习并掌握英文书信的种类、组成部分、信封的写法，写出语言地道、自然、通顺的书信对信息的沟通、事务的处理、友谊的增进至关重要。

英文书信的种类

英文书信包括联络感情的私人信件，事务往来的商务信件和社交信件。

英文书信的 6 大组成部分

英文书信一般有信头(heading−回信地址)、信内地址(inside address−收信人地址)、称呼(salutation)、正文(body)、信尾套语(complimentary closing)、签名(signature)6 部分组成。有的还有附件(enclosure 缩写为 Encl.或 Enc.)或附言(postscript 缩写为 P.S.)。常见的格式有两种：

Sample 1

1 Heading
(Date)

2 Inside Address

3 Salutation

4 Body

5Complimentary
Closing
6 Signature

Sample 2

1 Heading
2 Inside Address
(Date)
3 Salutation
4 Body

5 Complimentary Closing
6 Signature

1. 信头

有的信头已经印在信纸上，写信时只需在信头下端注上日期即可。如果没有，可在信纸的右上角写上信头，具体的位置要根据信的格式而定(见上表)。信头主要有齐头式(indented form)和斜列式(block form)，但随着时代的发展，信头也会有所变化，有的信件把信头写在信纸的正上方的中间。信头包括机关、单位、地址、电话号码和传真。比较熟悉或亲密的私人信件可以没有信头。

日期的写法可有多种，现举例说明：9 October 2005, 9 Oct. 2005, October 9 2005, 但在正式信函中不能用 Oct.这样的写法，更不能简写为 10/9/2005。

2. 信内地址(inside address)

英文书信的信内地址应与信封上的地址完全一样，包括收信人的姓名、地址。如果不是私人信件，还要加上个人称谓。如：

Mr. David Lamb President for advertising Mr. David Lamb
President for advertising

__________(address) ________(address) ________(address)

Professor Peter Smith
Department of Foreign languages
Henan University of Technology
Zhengzhou 450007
P.R. China

3. 称呼(salutation)

根据与收信人的关系可用不同的称呼。在商业信函中，可用 Dear Mr. (Mrs., Ms. , Miss) White；在有学位、头衔的人前可用 Dear Prof. (Dean, Mayor 等) Smith；在亲友之间，可用 Dear Smith (Wang, Brother, friend, Father,…等)；当不知道性别时，可用 Dear Sir or Madam 或 Dear Sir /Madam；当给单位写信时，可用 Dear Sirs。

4. 正文(body)

由开头、扩展和结语三部分组成。不同的信件其内容也不一样，但在开头里通常会交代写信人的目的，在结语里会简要说明要点或表示感谢，或表明希望。总的说来，一封好的信应态度诚恳，表达清楚、流畅，语言规范、正确、得体、简洁。

5. 信尾套语(complimentary closing)

Yours faithfully(商业信函中不知对方的姓名)
Yours sincerely(商业信函中知道对方的姓名)
Yours/ Yours ever(私人信函中表示友好)
Love/With love/Lovingly (私人信函中表示亲密)

6. 签名(signature)

私人信件中应亲笔签名；商业等正式信件中，除了打印的名字外还需手签或手写印刷体重新拼写一遍，以免出错。

7. 英文书信范例

1) 求职信(摘自《高等学校英语应用能力考试指导手册》)

136 Brownless Road
Catford, PL42EB
August19, 2000
Dear Mr. Bateman,

I saw your advertisement for an Assistant Manager in this week’s issue of The Hotelier and I should like to apply for the position.

I am enclosing my resume and a recent photograph.

As you see I have been Assistant Manager at the Granada Hotel in Madrid for a year and I would very much like to have experience of hotel work in England.

I am at present on holiday in England and staying with friends at the above address. I shall be returning to Spain at the end of the month.

Yours sincerely,

Maria Sanchez

2) 推荐信(摘自《实用英语综合训练和自测》)

To Whom It May Concern,

It is my pleasure to give Miss Li Zi a reference.

She was my assistant when I worked as Business Coordinator at the Nanjing office of the MacroHard Softwares, Inc.; and I am certainly sorry to lose her when I was transferred to the Beijing office.

Miss Li is an excellent assistant. She has been with our office for four years. From my observation of her, she was very diligent and talented, and has practical experience in software development. And she is always pleasant to everyone and always willing to help others.

I recommend her without reservation, as I know you will find her a most efficient and responsible employee.

Yours faithfully

Liu Zhe

信封的写法

发信人的地址一般写在信封的左上角。收信人的地址一般置于信封中下的位置,信封上收信人的姓名、地址、称谓与信内地址完全一致。邮票贴在信封的右上角。对邮局的指示语，如 Air Mail, Sea Mail, Registered 等应写在紧挨邮票的下端；对收信人的指示语如 Personal , Private , Manuscripts 等应写在信封的左下角。

Exercises

1. Translate the following into Chinese.

(1) Some manufacturers offer two designs, and in some cases, all three designs, depending on horsepower ranges and application requirements.

(2) For the moment, however, the most frequently stated advantages and disadvantages of these three most commonly used types of inverters are listed as follows.

(3) In other words, 90% of the problem is in proper selection of the motor and operating options, and 10% of the problem is whether to select PWM or AVI or CSI.

2. Translate the following into English.

(1) 发光二极管是一种将外加电压转变成光的半导体二极管，用于数字显示，如电子秤和自动化仪表。

(2) 这只电容器的容量比实际所需的容量大。

(3) 力是一个矢量，它可使受力物体沿力的方向产生加速度。

Reading Material Performance Comparisons of PWM, AVI, And CSI

Each of these types of inverters is usually designed to allow operation within these motor constraints. The differences are in the techniques used to generate volts/hertz, adjustable frequency, and any inherent design limitations on minimum and maximum frequency.

It is not the intent of this book to take sides or to pass judgment on the relative merits or pros and cons of the three types of inverters. They all do a good job when properly applied and properly designed. Some manufacturers offer two designs, and in some cases, all three designs, depending on horsepower ranges and application requirements.

For the moment, however, the most frequently stated advantages and disadvantages of these three most commonly used types of inverters are listed as follows:

AVI Advantages

(1) Basic simplicity: it has simple logic and can be operated open loop. (No feedback of amperes or volts is required for steady-state operation)

(2) A single controller can be used with more than one motor.

(3) Reliability is good, somewhat better than for PWM types.

(4) Voltage stresses on motor insulation are relatively low.

(5) Can be designed for up to 500 Hz operation.

AVI Disadvantages

(1) Speed range is limited because of motor cogging at 6 Hz and below.

(2) DC link stability can be a problem at low speeds because of motor interaction with DC link filter elements.

(3) Requires an additional set of power devices in the input stage if regeneration back to the AC line is desired.

(4) To obtain extended ride-through capability on incoming power loss, a DC chopper must be added to the DC link.

(5) Input power factor is poor below base speed.

PWM Advantages

(1) A wider speed range (below rated frequency) is possible.

(2) Can be used with more than one motor.

(3) Input power factor is good at all frequencies.

(4) Diode input stage allows ride-through on input power interruption.

PWM Disadvantages

(1) Logic circuitry is relatively complex.

(2) Operation above 120~150 Hz is difficult.

CSI Advantages

(1) Capable of regeneration back to the AC line because DC link bus polarity can be reversed.

(2) Large DC link filter inductor and regulated power supply acts as a current limiter, making it easier to apply protective fuses.

(3) Ability to ride through power-line interruptions.

(4) Thyristors in output stage can be commercial grade.

CSI Disadvantages

(1) Cogging can occur at speeds below 6 Hz.

(2) DC link filter inductor is large, costly, and contributes to losses and enclosure size.

(3) Can cause high-voltage spikes on motor terminals.

(4) Usually not possible to use with more than one motor.

(5) Motor power factor appears on the incoming line to the controller.

(6) Voltage clamping devices lower overall efficiency.

(7) May require special tuning to motor parameters.

Summary of Performance Comparisons

The technical references cover the various advantages and disadvantages of the different types of inverters in more detail. For purposes of this book it is sufficient to state that the great majority of items that must be considered when selecting an inverter to be applied to a particular application are the same, regardless of the type of inverter. In other words, 90% of the problem is in proper selection of the motor and operating options, and 10% of the problem is whether to select PWM or AVI or CSI.

New Words and Phrases

1. volt [vəʊlt]	n.	伏特(电压单位)
2. pros and cons		赞成与反对，优点与缺点
3. horsepower [ˈhɔːspaʊə(r)]	n.	(机)马力(缩写：HP)
4. insulation [ɪnsjʊˈleɪʃ(ə) n]	n.	绝热，绝缘，隔离；绝缘体，绝缘材料
5. cogging [ˈkɔgiŋ]	n.	[建]接头；[集合词]榫；切削齿；齿槽效应
6. rated [ˈreitid]	adj.	定价的，额定的
7. fuse [fjuːz]	n.	保险丝，熔丝
	v.	熔合
8. enclosure [inˈkləuʒə]	n.	圈地，围绕，封入；外壳，盒子，套
9. spike [spaik]	n.	穗，长钉；尖峰信号，测试信号
	v.	用大钉钉，用长而尖之物刺，阻止，穿刺
10. clamping [ˈklæmpiŋ]	n.	箝位，箝位电路

Lesson 25 Modeling a Simple Continuous System Based on MATLAB

What Is MATLAB

MATLAB is a high-performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation. [1] Typical uses include:

- Math and computation
- Algorithm development
- Data acquisition
- Modeling, simulation, and prototyping
- Data analysis, exploration, and visualization
- Scientific and engineering graphics
- Application development, including graphical user interface building

MATLAB is an interactive system whose basic data element is an array that does not require dimensioning. This allows you to solve many technical computing problems, especially those with matrix and vector formulations, in a fraction of the time it would take to write a program in a scalar noninteractive language such as C or Fortran.

The name MATLAB stands for matrix laboratory. MATLAB was originally written to provide easy access to matrix software developed by the LINPACK and EISPACK projects. [2] Today, MATLAB engines incorporate the LAPACK and BLAS libraries, embedding the state of the art in software for matrix computation.

MATLAB has evolved over a period of years with input from many users. In university environments, it is the standard instructional tool for introductory and advanced courses in mathematics, engineering, and science. In industry, MATLAB is the tool of choice for high-productivity research, development, and analysis.

MATLAB features a family of add-on application-specific solutions called toolboxes. Very important to most users of MATLAB, toolboxes allow you to learn and apply specialized technology. [3] Toolboxes are comprehensive collections of MATLAB functions (M-files) that extend the MATLAB environment to solve particular classes of problems. Areas in which toolboxes are available include signal processing, control systems, neural networks, fuzzy logic, wavelets, simulation, and many others. [4]

The MATLAB system consists of five main parts:

Development Environment. This is the set of tools and facilities that help you use MATLAB functions and files. Many of these tools are graphical user interfaces. It includes the MATLAB desktop and Command Window, a command history, an editor and debugger, and browsers for viewing help, the workspace, files, and the search path.

The MATLAB Mathematical Function Library. This is a vast collection of computational algorithms ranging from elementary functions like sum, sine, cosine, and complex arithmetic, to more sophisticated functions like matrix inverse, matrix eigenvalues, Bessel functions, and fast Fourier transforms.

The MATLAB Language. This is a high-level matrix/array language with control flow statements, functions, data structures, input/output, and object-oriented programming features. It allows both "programming in the small" to rapidly create quick and dirty throw-away programs, and "programming in the large" to create complete large and complex application programs.

Graphics. MATLAB has extensive facilities for displaying vectors and matrices as graphs, as well as annotating and printing these graphs. It includes high-level functions for two-dimensional and three-dimensional data visualization, image processing, animation, and presentation graphics. [5] It also includes low-level functions that allow you to fully customize the appearance of graphics as well as to build complete graphical user interfaces on your MATLAB applications.

The MATLAB Application Program Interface (API). This is a library that allows you to write C and Fortran programs that interact with MATLAB. It includes facilities for calling routines from MATLAB (dynamic linking), calling MATLAB as a computational engine, and for reading and writing MAT-files.

Modeling a Simple Continuous System. To model the differential equation

$$x'(t) = -2x(t) + u(t) \tag{25-1}$$

where $u(t)$ is a square wave with an amplitude of 1 and a frequency of 1 rad/sec. [6] The **Integrator** block integrates its input x' to produce x. Other blocks needed in this model include a **Gain** block and a **Sum** block. To generate a square wave, use a **Signal Generator** block and select the Square Wave form but change the default units to radians/sec. Again, view the output using a **Scope** block. Gather the blocks and define the gain.

In this model, to reverse the direction of the **Gain** block, select the block, and then use the **Flip Block** command from the **Format** menu. To create the branch line from the output of the **Integrator** block to the **Gain** block, hold down the **Ctrl** key while drawing the line. Now you can connect all the blocks. See Fig. 25.1.

An important concept in this model is the loop that includes the **Sum** block, the **Integrator** block, and the **Gain** block. In this equation, x is the output of the **Integrator** block. It is also the input to the blocks that compute x', on which it is based. This relationship is implemented using a loop.

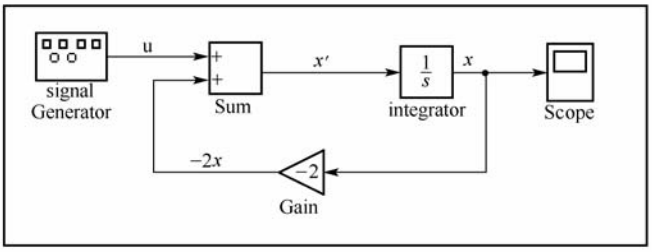


Fig. 25.1 One model of the differential equation

The Scope displays x at each time step. For a simulation lasting 10 seconds, the output looks like Fig. 25.2.

The equation you modeled in this example can also be expressed as a transfer function. The model uses the **Transfer Fcn** block, which accepts *u* as input and outputs *x*. So, the block implements *x/u*. If you substitute *sx* for *x´* in the above equation, you get

$$sx = -2x + u \tag{25-2}$$

Solving for x gives

$$x = u/(s+2) \tag{25-3}$$

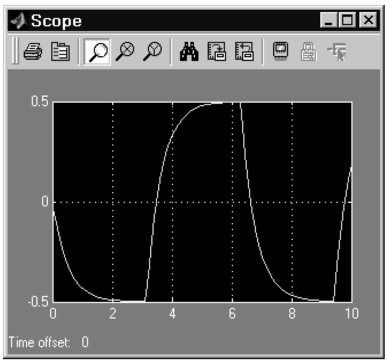


Fig. 25.2 Output of x displayed by scope

or,

$$x/u = 1/(s+2) \tag{25-4}$$

The **Transfer Fcn** block uses parameters to specify the numerator and denominator coefficients. In this case, the numerator is 1 and the denominator is *s+2*. Specify both terms as vectors of coefficients of successively decreasing powers of *s*. In this case the numerator is [1] (or just 1) and the denominator is [1 2]. The model now becomes quite simple. See Fig. 25.3.

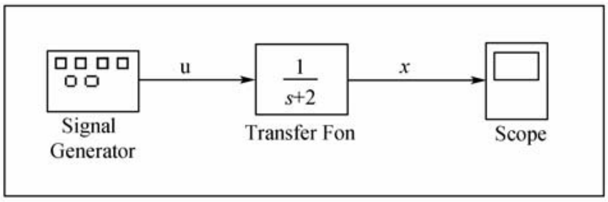


Fig. 25.3 Another model of the differential equation

The results of this simulation are identical to those of the previous model.

New Words and Phrases

1. performance [pəˈfɔːməns] n. 履行，执行，成绩，性能，表演，演奏
2. programming [ˈprəugræmiŋ] n. 规划，设计

3. notation [nəu'teiʃən]	n.	记号；符号；注释
4. acquisition [ˌækwi'ziʃən]	n.	获(取)得；发现，探测；捕获，拦截；目标显示；获得(添加)物，收获，学识
5. prototyping ['prəutətaip]	n.	原型；模型；典型；榜样
6. graphics ['græfiks]	n.	(作单数用)制图法，制图学，图表算法，图形
7. interface ['intə(:)ˌfeis]	n.	分界面；（两个体系间的）接合部位，边缘区域；[计]界面，接口
8. interactive [ˌintər'æktiv]	adj.	互相作用的；[计]交互式的
9. dimensioning [di'menʃən]	n.	[数]次，元，维(数)；[物]因次，量纲 [pl.]容积，面积，范围，规模
10. matrix ['meitriks]	n.	[数]矩阵
11. vector ['vektə]	n.	[数]向量，矢量，带菌者
	vt.	无线电导引
12. formulation [ˌfɔːmju'leiʃən]	n.	用公式表示，明确地表达，作简洁陈述
13. fraction ['frækʃən]	n.	小部分，片断，分数
14. scalar ['skeilə]	adj.	梯状的，分等级的，数量的，标量的
	n.	数量，标量
15. noninteractive ['nɔnintə'æktiv]	adj.	非交互的
16. incorporate [in'kɔːpəreit]	adj.	合并的，结社的
	vt.	合并，使组成公司，具体表现
	vi.	合并，组成公司
17. productivity [ˌprɔdʌk'tiviti]	n.	生产力；生产率
18. toolbox [ˋtuːlbɔks]	n.	工具箱
19. neural ['njuərəl]	adj.	神经系统的，神经中枢的，背的
20. network ['netwəːk]	n.	网状物，广播网，[计]网络
21. wavelet ['weivlit]	n.	微(子，弱，小)波；基元(成分)波；碎(小)浪
22. file [fail]	n.	文件，档案，锉刀
	vt.	把……归档，提出(申请等)，锉
	vi.	列队行进，用锉刀锉
23. desktop ['desktɔp]	n.	[计]桌面；桌上型电脑
24. debugger [diː'bʌgə]	n	[计]调试器
25. browser [braʊzə(r)]	n	浏览器，吃嫩叶的动物，浏览书本的人
26. arithmetic [ə'riθmətik]	n.	算术，算法
27. sophisticated [sə'fistikeitid]	adj.	(很)复杂的，高级的，精致的，尖端的，需要专门操作技术的；成熟的，完善的采用了先进技术的；掺杂(过)的，不纯的；老练的，非常有经验的

28. inverse [ˈinˈvəːs]	adj.	倒转的，反转的
	n.	反面
	v.	倒转
29. eigenvalue [ˋaɪgən,væljuː]	n.	[数.物]特征值
30. Bessel functions		贝塞耳函数 [贝塞耳(Friedrich Wilhelm，1784—1846，德国天文学家)]
31. Fourier [ˈfuriei]		傅立叶(①姓氏②Francois Marie Charles，1772—1837，法国空想社会主义者，社会改革家 ③Jean Baptiste Joseph，1768—1830，法国数学家，物理学家)
32. linking [ˈliŋkiŋ]	n.	耦合，结合；联系；连接；[化]键合
33. model [ˈmɔdl]	n.	样式，型，模范，典型，模型，原型，模特儿
	vt.	模仿
	v.	模拟
34. square [skwɛə]	n.	正方形，广场，平方，直角尺
	adj.	正方形的，四方的，直角的，正直的，公平的，结清的，平方的，彻底的
	adv.	成直角地，正直地，公平地，坚定地
	v.	使成方形，弄平，使直，与……一致，符合，自乘，结算
35. amplitude [ˈæmplitjuːd]	n.	(振，波，摆)幅，幅度；射程，距离，范围，作用半径；广阔，充足，丰富
36. default [diˈfɔːlt]	n.	默认(值)，缺省(值)，不履行责任；[律]缺席
	v.	疏怠职责，缺席，拖欠，默认
37. radian [ˈreidjən]	n.	弧度
38. scope [skəup]	n.	范围，范畴，领域；余地；机会；观测仪器(如显微镜，望远镜，示波器等)
39. display [dɪˈspleɪ]	vt.	陈列，展览，显示
	n.	陈列，展览，显示；显示，显示器
40. numerator [ˈnjuːməreitə]	n.	[数](分数的)分子；计算者
41. denominator [diˈnɔmineitə]	n.	[数]分母，命名者
42. power [ˈpauə]	n.	能力，力量，动力，权力，[数]幂，[物]功率
	vt.	使……有力量，激励

Notes

[1] It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation.

它集计算、可视化和编程于一体，在这个便于使用的环境中，问题和解决方案都可以用熟悉的数学符号来表示。

[2] MATLAB was originally written to provide easy access to matrix software developed by the LINPACK and EISPACK projects.

MATLAB 起初是由 LINPACK 和 EISPACK 项目开发出来的简便矩阵软件。

[3] Very important to most users of MATLAB, toolboxes allow you to learn and apply specialized technology.

对多数 MATLAB 用户来说很重要的一点是，使用工具箱可以学习和应用专业技术。

[4] Areas in which toolboxes are available include signal processing, control systems, neural networks, fuzzy logic, wavelets, simulation, and many others.

提供工具箱的领域包括信号处理、控制系统、神经网络、模糊控制、小波、仿真和其他许多方面。

[5] It includes high-level functions for two-dimensional and three-dimensional data visualization, image processing, animation, and presentation graphics.

它包括一些高级函数，这些高级函数可用于二维和三维数据可视化、图像处理、动画和图形再现。

[6] To model the differential equation $x'(t) = -2x(t) + u(t)$, where u(t) is a square wave with an amplitude of 1 and a frequency of 1 rad/sec.

搭建微分方程 $x'(t) = -2x(t) + u(t)$ 的模型，其中 $u(t)$是幅值为 1、频率为 1 弧度/秒的方波。

Application Skills　科技文献的检索

文献是在存贮、检索、利用或传递记录信息的过程中，可作为一个单元处理的，在载体内、载体上或依附载体而存贮有信息或数据的载体。文献具有知识、载体、记录方式三要素。文献本身固有的性质分别是知识性、客观物质性、人工记录性和动态发展性。

随着科学技术的迅速发展，科技文献，尤其是尖端科学的文献增加速度更快，如原子能文献每 2～3 年就翻一番，且倍增周期逐年缩短。中国期刊全文数据库 2002 年为 1197770 篇，2003 年为 1416570 篇，目前为 18635892 篇。科技文献种类繁多，有学术论文、科技报告、学位论文和科技会议文献等原始文献，也有在此基础上经整理、加工、压缩、提炼后编制成的各种检索工具，如书目、题录、索引、文摘、百科全书、手册、年鉴和名录等。进行科学研究、撰写学位和学术论文、进行毕业设计、从事产品的开发和进行发明创造等工作时，都要检索相关的文献。因此，文献检索是科技人员必备的基本技能，是科学研究的先期工作，是知识更新的手段，也是能力培养(学习能力)的重要途径。

1. 文献检索的要求和步骤

(1) 掌握科技文献检索和资料查询的基本方法，包括直接检索法和间接检索法。

(2) 了解常用文献检索工具的类型、结构及其使用方法，特别是与本专业相关的各种索引、文摘、书目、年鉴等。

(3) 了解与本学科专业相关的各种科技文献的名称、种类和级别等。

(4) 选择题目：题目一般应是本科生的毕业论文、毕业设计题目。

(5) 搜集资料和阅读文献：根据选定的主题，利用各种检索工具，采用直接检索和间接检索相结合的方法，搜集和阅读相关文献资料，在阅读文献时要注意做好记录(卡片、笔记等)。

(6) 分析归纳和草拟提纲：对于查找和搜集到的大量文献资料要进行分析、归纳、整理和取舍，然后按照“内容要求”的内容草拟提纲，对文献综述的全文进行整体构思和结构设计。

(7) 撰写综述(论文)：在大量阅读文献资料的基础上，根据主题进行综合论述，并撰写成文。

2. 文献的形式

各类专业文献种类繁多，形态各异。从形式/载体。上分为以下几种：

(1) 印刷型(Printed form)。印刷型是以纸张为存贮介质，以手写、印刷为记录手段而存在的一种传统的文献形式。

(2) 缩微型 (Microform)。缩微型以感光材料为存贮介质，以缩微照相为记录手段而存在的一种文献形式。

(3) 声像/视听型(Audio-Visual form)。声像/视听型又称为视听资料或直感资料，以磁性材料和光学材料为存贮介质。

(4) 机读/电子型(Machine Readable form)。机读/电子型全称为计算机可读型文献，以磁性材料(磁带、磁盘或光盘等)为存贮介质。3. 文献的级别

专业文献从级别上可分为下面几种：

(1) 一次文献/信息(primary Literature/info)，即原始文献，如期刊文献(Journal literature)、科技报告(Sci-Tech report)、学术会议论文集(Proceedings)、专利(Patent specification)、论文(Paper)、学位论文(Thesis)等。

(2) 二次文献/信息(secondary literature /info)，即检索工具，如条目(entry reference citation record)、文摘(Abstract)、索引(Index)、目录(Catalog)、题录(Bibliography)等。

(3) 三次文献(Tertiary literature/info)，如词典或百科全书等参考书(Reference book)，属于参考性文献。

4. 类型与识别

文献的类型有很多，一般分为以下几类：

(1) 科技图书(Sci-Tech book)，主要包括专著(Monograph)、文选(Anthology)、教材(Textbook)和参考书(Reference book)等。

(2) 科技期刊(Sci-Tech Journal)，主要包括杂志(magazine)、不定期的连续出版物(serial)和期刊(periodical)等。

(3) 科技报告(Sci-Tech Report)。

(4) 专利文献(Patent Document)，主要包括专利说明书(Patent specification)和专利公告(bulletin)等。

(5) 会议文献(Conference paper)。

(6) 学位论文(Dissertation, Thesis)。

(7) 其他标准文献、产品资料、技术档案、政府出版物等。

5. 文献/信息检索(Literature/Information Retrieval/Access)

文献检索的手段分为手检(书本型工具/期刊)和机检(数据库系统)。其中手检是对相关的印刷型资源进行检索，包括各种检索工具和专业期刊。电子、电气、计算机、自动化、信息技术等相关专业的中文核心期刊如表 25-1 所示。

表 25-1　主要中文核心期刊

N 自然科学总论	1. 系统工程理论与实践　2. 系统工程　3. 系统工程与电子技术　4. 系统工程学报　5. 系统工程理论方法应用　6. 自然辩证法研究　7. 科学　8. 管理科学学报　9. 自然科学史研究　10. 自然杂志　11. 科学技术与辩证法　12. 中国科学基金　13. 中国科技史料
TH 机械、仪表工业	1. 机械工程学报　2. 中国机械工程　3. 摩擦学学报　4. 机械科学与技术　5. 机械设计　6. 仪器仪表学报　7. 计算机集成制造系统-CIMS　8. 润滑与密封　9. 机械传动　10. 机床与液压　11. 工程机械　12. 机械设计与研究　13. 起重运输机械　14. 轴承　15. 流体机械　16. 光学精密工程　17.制造业自动化　18.机械设计与制造　19. 水泵技术　20. 液压与气动　21. 制造技术与机床　22. 仪表技术与传感器　23. 压力容器
TJ 武器工业	1. 兵工学报　2. 弹道学报　3. 火炮发射与控制学报　4. 现代防御技术　5. 探测与控制学报　6. 战术导弹技术　7. 火力与指挥控制　8. 弹箭与制导学报　9. 兵器材料科学与工程　10. 飞航导弹　11. 火工品
TK 能源与动力工程	1. 工程热物理学报　2. 内燃机学报　3. 中国电机工程学报　4. 动力工程　5. 热能动力工程　6. 内燃机工程　7. 太阳能学报　8. 中国电力　9. 热力发电　10. 汽轮机技术　11. 锅炉技术　12. 电站系统工程　13. 燃烧科学与技术　14. 小型内燃机与摩托车　15. 车用发动机　16. 华东电力
TL 原子能技术类	1. 原子能科学技术　2. 核动力工程　3. 核科学与工程　4. 核技术　5. 核电子学与探测技术　6. 强激光与粒子束　7. 辐射防护　8. 高能物理与核物理　9. 核聚变与等离子体物理　10. 核化学与放射化学　11. 原子核物理评论　12. 辐射研究与辐射工艺学报　13. 核农学报　14. 同位素　15. 铀矿冶

(续)

TM 电工技术	1. 中国电机工程学报 2. 电工技术学报 3. 电力系统自动化 4. 电网技术 5. 高电压技术 6. 电池 7. 电源技术 8. 电化学 9. 电工电能新技术 10. 中国电力 11. 高压电器 12. 继电器 13. 电力电子技术 14. 变压器 15. 电工技术杂志 16. 电气传动 17. 中小型电机 18. 低压电器 19. 电力自动化设备 20. 蓄电池 21. 微电机 22. 微特电机 23. 电机与控制学报 24. 电力系统及其自动化学报 25. 电气自动化 26. 电测与仪表 27. 大电机技术 28. 华北电力大学学报
TN 无线电电子学，电信技术	1. 电子学报 2. 中国激光 3. 半导体学报 4. 通信学报 5. 电子与信息学报 6. 光电子、激光 7. 电子科技大学学报 8. 激光杂志 9. 激光技术 10. 西安电子科技大学学报 11. 红外与毫米波学报 12. 量子电子学报 13. 应用激光 14. 系统工程与电子技术 15. 电子技术应用 16. 半导体光电 17. 激光与红外 18. 电信科学 19. 半导体技术 20. 固体电子学研究与进展 21. 现代雷达 22. 信号处理 23. 电波科学学报 24. 电视技术 25. 压电与声光 26. 北京邮电大学学报 27. 激光与光电子学进展 28.红外与激光工程 29.电路与系统学报 30. 光电工程 31. 光通信研究 32. 微电子学 33. 通信技术 34. 光通信技术 35. 液晶与显示 36. 微波学报 37. 广播与电视技术 38. 真空科学与技术学报 39. 数据采集与处理 40. 红外技术 41. 电子元件与材料
TP 自动化技术，计算机技术	1. 计算机学报 2. 软件学报 3. 计算机研究与发展 4. 自动化学报 5. 计算机科学 6. 控制理论与应用 7. 计算机辅助设计与图形学学报 8. 计算机工程与应用 9. 模式识别与人工智能 10. 控制与决策 11. 小型微型计算机系统 12. 计算机工程 13. 计算机应用 14. 信息与控制 15. 机器人 16. 中国图像图形学报.A 版 17. 计算机应用研究 18. 系统仿真学报 19. 计算机集成制造系统-CIMS 20. 遥感学报 21. 中文信息学报 22. 微计算机信息 23. 数据采集与处理 24.微型机与应用 25. 传感器技术 26. 传感技术学报 28. 计算机应用与软件 29. 微型计算机 30. 微电子学与计算机
TV 水利工程	1. 水利学报 2. 泥沙研究 3. 和海大学学报.自然科学版 4. 水利水电技术 5. 人民黄河 6. 水力发电 7. 水科学进展 8. 人民长江 9. 岩石力学与工程学报 10. 水力发电学报 11. 水利水运工程学报 12. 中国农村水利水电 13. 长江科学院院报 14. 水利水电科技进展
V 航空，航天	1. 航空学报 2. 空气动力学学报 3. 推进技术 4. 宇航学报 5. 航空动力学报 6. 北京航空航天大学学报 7. 南京航空航天大学学报 8. 中国空间科学技术 9. 固体火箭技术 10. 复合材料学报 11. 飞航导弹 12. 国际航空 13. 飞行力学 14. 宇航材料工艺 15. 中国航天 16. 流体力学实验与测量 17. 航天控制 18. 导弹与航天运载技术 19. 上海航天 20. 航空维修与工程 21. 电光与控制

计算机检索包括光盘数据库检索、网络数据库检索(比较流行的检索方式)和互联网信息检索(使用搜索引擎进行互联网信息检索)。

目前常用的中文网络数据库有 CNKI 系列数据库(www.cnki.net，包括中国期刊全文数据库、中国优秀博硕论文数据库和中国专利数据库)、超星数字图书馆(www.ssreader.com)、万方数据库(http://periodicals.wanfangdata.com.cn/qikan)、维普数据库(www.cqvip.com)等。

英文数据库有 CSA 数据库、Springer LINK 全文电子期刊、EBSCO 数据库、OCLC 数据库、IEL 数据库、《不列颠百科全书》网络版、WorldSciNet 电子期刊等。

互联网信息检索是指借助于搜索引擎进行互联网信息检索，常用的 WWW 搜索引擎主要有：

http://www.google.com

http://www.yahoo.com

http://www.baidu.com

http://e.pku.edu.cn

http://www.sowang.com/

除了常规的 WWW 搜索引擎外，还可以使用 FTP 搜索引擎，其功能是搜集匿名 FTP 服务器提供的目录列表以及向用户提供文件信息的查询服务。由于 FTP 搜索引擎专门针对各种文件，因而相对 WWW 搜索引擎，寻找软件、图像、电影和音乐等文件时，使用 FTP 搜索引擎更加便捷。常用的 FTP 搜索引擎主要有：

http://www.philes.com

http://www.alltheweb.com

http://www.filesearching.com

北大天网 FTP：http://bingle.pku.edu.cn

清华大学：ftp://www.lib.tsinghua.edu.cn/，ftp://ftp.net.edu.cn/

北京大学：http://bingle.pku.edu.cn，ftp://www.lib.pku.edu.cn/，ftp://ftp.pku.edu.cn/

中国科学技术大学：ftp://ftp.ustc.edu.cn/

浙江大学：ftp://ftp.zju.edu.cn/

北京邮电大学：ftp://ftp.bupt.edu.cn/，ftp://ftp.buptnet.edu.cn/

华中理工大学：ftp://ftp.whnet.edu.cn/

上海交通大学：ftp://ftp.shnet.edu.cn/，ftp://mssite.sjtu.edu.cn/

哈尔滨工业大学：ftp://ftp.hit.edu.cn/

西安交通大学：ftp://ftp.xjtu.edu.cn/，ftp://ftp.xanet.edu.cn/，ftp://ftp.pevirc.xjtu.edu.cn/

香港中文大学：ftp://ftp.cuhk.hk/，ftp://ftp.cuhk.edu.hk/，ftp://ftp.arts.cuhk.edu.hk/

6. *检索点/途径*(Access Point)

检索点是检索系统预先设置的，用户可用于检索的途径。

(1) 分类(Classified)按文献所属的学科类别来检索文献。在检索文献之前应根据课题的主要内容以及数据库所采用的分类表，确定分类号。

(2) 主题(Subject)从文献的主题概念出发，通过主题词或关键词检索文献。

(3) 题名(Title)根据文献题名来检索文献。文献题名主要指书名、刊名、篇名等。题名允许中、英文混合或者是题名的一部分。

(4) 著者(Author)通过著者(个人著者、团体著者(Corporate Author/Authors’Affiliation))的名称来检索文献。

(5) 号码检索通过号码(Code/Coden)如 ISBN(International Standard Book Number)号、ISSN 号、专利号、标准号、报告号等来检索文献。

Exercises

1. Translate the following into Chinese.

(1) Simulink is a software package for modeling, simulating, and analyzing dynamic systems.

(2) Using scopes and other display blocks, you can see the simulation results while the simulation is running.

(3) The simulation results can be put in the MATLAB workspace for postprocessing and visualization.

2. Translate the following into English.

(1) MATLAB 是矩阵实验室的缩写，在自动控制和通信系统的分析和设计中是十分重要工具。

(2) 在进一步讨论这个问题之前，阐述以下几个概念是很重要的。

(3) 计算机有电子管式的、晶体管式的和集成电路式等几种类型。

Reading Material　What Is Simulink

Simulink is a software package for modeling, simulating, and analyzing dynamic systems. It supports linear and nonlinear systems, modeled in continuous time, sampled time, or a hybrid of the two. Systems can also be multirate, i.e., have different parts that are sampled or updated at different rates.

For modeling, Simulink provides a graphical user interface (GUI) for building models as block diagrams, using click-and-drag mouse operations. With this interface, you can draw the models just as you would with pencil and paper (or as most textbooks depict them) . This is a far cry from previous simulation packages that require you to formulate differential equations and difference equations in a language or program. Simulink includes a comprehensive block library of sinks, sources, linear and nonlinear components, and connectors. You can also customize and create your own blocks. For information on creating your own blocks, see the separate Writing S-Functions guide.

Models are hierarchical, so you can build models using both top-down and bottom-up approaches. You can view the system at a high level, then double-click blocks to go down through the levels to see increasing levels of model detail. This approach provides insight into how a model is organized and how its parts interact.

After you define a model, you can simulate it, using a choice of integration methods, either from the **Simulink** menus or by entering commands in the MATLAB Command Window. The menus are particularly convenient for interactive work, while the command-line approach is very useful for running a batch of simulations (for example, if you are doing Monte Carlo simulations or want to sweep a parameter across a range of values) . Using scopes and other display blocks, you can see the simulation results while the simulation is running. In addition, you can change parameters and immediately see what happens, for "what if" exploration. The simulation results can be put in the MATLAB workspace for postprocessing and visualization.

Model analysis tools include linearization and trimming tools, which can be accessed from the MATLAB command line, plus the many tools in MATLAB and its application toolboxes. And because MATLAB and Simulink are integrated, you can simulate, analyze, and revise your models in either environment at any point.

New Words and Phrases

1. hybrid [ˈhaibrid]	n.	杂种，混血儿，混合物
	adj.	混合的，杂种的
2. graphical [ˈgræfikəl]	adj.	=graphic 图(解，式，示)的，(用)图(表)示的，曲线图的；绘图(画)的，雕刻的，印刷的；生动的，(轮廓)鲜明的
	n.	图解(表)，地图
3. sink [siŋk]	vi.	沉下，(使)下沉
	n.	水槽，水池；接收器
4. nonlinear [ˈnɔnˈliniə]	adj.	非线性的
5. hierarchical [ˌhaiəˈrɑːkikəl]	adj.	分等级的
6. menu [ˈmenjuː]	n.	菜单；[计]程序命名表，菜单
7. batch [bætʃ]	n.	一批，一组，大量；[计]批量
8. postprocessing [ˌpəustˌprəuˈsesiŋ]	n.	后加工
9.trimming [ˈtrimiŋ]	n.	调整，平衡；修剪，修理(原形 trim)
10. revise [riˈvaiz]	vt.	修订，校订，修正，修改

附录 1　常用专业词汇表

0 型系统	type 0 system
1 型系统	type 1 system
2 型系统	type 2 system
W 平面	w-plane
Z 变换	z-transform
Z 传递函数	z-transfer function
Z 平面	z-plane
Z 域	z-domain
安全系数	safety factor
按钮	push bottom, press-button
靶式流量变送器	target flow transmitter
白箱测试法	white box testing approach
白噪声	white noise
半导体可控整流器，可控硅	semiconductor controlled rectifier(SCR)
半径	radius(复数为 radii)
半实物仿真	semi-physical simulation
半自动化	semi-automation
保险丝	fuse
被控/控制对象	controlled plant
被控/受控变量	controlled variable
比冲	specific impulse
比例积分微分控制器，PID 控制器	proportional plus integral plus derivative controller
比特，二进制的一位	bit
闭环传递函数	closed loop transfer function
闭环极点	closed loop pole
闭环控制系统	closed loop control system
闭环零点	closed loop zero
闭环增益	closed loop gain
编码	encode
编码器，编码装置	coder
编译程序，编译器	compiler
变换矩阵	transformation matrix
变结构控制系统	variable structure control system

变频电气传动	variable frequency electric drive
变送器，发射机	transmitter
标记	sentinel
标识符	identifier
表压力	gage pressure
并联电抗器	shunt reactor
并联电容器	shunt capacitor
伯德图	Bode diagram
不间断电源	uninterruptible power supply(UPS)
不间断工作制，长期工作制	uninterrupted duty
步进电机	stepping/stepper/step motor
步进电气传动	step motion electric drive
步进控制	step/step-by-step control
采样频率	sample frequency
采样系统	sampling system
参数，参量	parameter
操作流程图	operating flow chart
测量范围	measuring range
测试信号	test signal
策略函数	strategic function
差动放大器	differential amplifier
差压控制器	differential pressure controller
场效应晶体管	field effect transistor(FET)
超声厚度计	ultrasonic thickness meter
超声流量计	ultrasonic flowmeter
超声物位计	ultrasonic levelmeter
称重传感器	weighing cell
城市规划	urban planning
程序设计员	programmer
弛张振荡器	relaxation oscillator
初始电压	initial voltage
初始条件	initial condition
触发器	flip-flop
穿越频率，交越频率	cross-over frequency
传递函数矩阵	transfer function matrix
传递函数模型	transfer function model
传感器	sensor, transducer
传输延迟	transport lag

串级控制	cascade control
串级系统	cascade system
串联补偿	cascade/series compensation
串行的，连续的	serial
磁存储器	magnetic storage
磁道	track
磁极	magnetic pole
磁力矩	magnetic moment
磁盘	disc, disk
磁头臂，存取臂	access arm
磁心存储器	core storage, core store
磁滞现象	hysteresis
次优控制	suboptimal control
次优系统	suboptimal system
次优性	suboptimality
从站	slave station
粗调	coarse adjustment
存储单元	memory cell/location
存储器	memory, storage
存取时间	access time
打印机	printer
打印输出	printout
代码，编码	code
单变量控制系统	single variable control system
单端谐振变换器	single-ended resonant converter
单环协调策略	single loop coordination strategy
单回路控制器	single loop controller
单回路控制系统	single loop control system
单级过程	single level process
单结晶体管	unijunction transistor(UJT)
单输入单输出控制系统	single input single output control system(SISO)
单位反馈	unit feedback
单位阶跃函数	unit step function
单位圆	unit circle
单相整流	single-phase rectification
单元测试	unit testing
单值非线性	single value nonlinearity
单自由度陀螺仪	single degree of freedom gyro

等待时间	latency time
低纹波	low-ripple
地线	earth lead/wire, ground wire/leak
地址	address
电传打字机	teleprinter
电磁阀	solenoid valve
电感器	inductor
电机	motor
电力传输	power transmission
电力电子学	power electronics
电流表，安培计	ammeter
电流互感器	current transformer
电流源逆变器	current-source inverters(CSI)
电路，线路	circuit
电气系统	electric system
电容器	capacitor, condenser, nichicon
电容量，电容	capacity
电枢绕组	armature winding/coil
电刷	brush
电压调节器	voltage regulator
电压互感器	voltage transformer
电压降	voltage/potential drop
电压上升率	rate-of-rise of voltage
电压源逆变器	voltage-source inverters(VSI)
电远传压力表	transmissible pressure gauge
电阻	resistance
电阻器	resistor
阻抗，全电阻	impedance
调试	debugging, troubleshoot
调速系统	speed control system
调用指令	call instruction
定常/非时变/时不变系统	time-invariant system
定点精[确]度	station accuracy
定理证明	theorem proving
定时	timing
定子	stator
动圈式仪表	moving coil meter
动态控制	dynamic control
动态偏差	dynamic deviation

动态响应	dynamic response
短路保护	short-circuit protection
短期工作制	short time duty
短期计划	short term planning
短期记忆	short term memory(SIM)
断路器	circuit breaker
队决策理论	team decision theory
队论	team theory
多回路控制	multiloop control
额定电流	current rating/rated current
额定电压	voltage rating/rated voltage
额定负载	nominal/rated load
额定马力	rated horsepower
额定容量	rated capacity
额定转速	rated speed
扼流圈/节流圈	choke coil
二次电压	secondary voltage
二极管	diode
二进制码	binary code
二进制位，二进制数字	binary digit
二维/2D 系统	two dimensional system
二位控制器	two state/step controller
发射极，发射器	emitter
翻译程序，翻译器	translator
反磁性的	diamagnetic, antimagnetic
反馈控制	feedback control
反偏置	reverse biased
反转触发器	toggle flip-flop
方法库	way base(WB)
方法库管理系统	way base management system(WBMS)
仿真，模拟	simulation
仿真/模拟	simulation
仿真[方]框图	simulation block diagram
仿真程序	simulation program
仿真方法学	simulation methodology
仿真工作站	simulation work station
仿真过程	simulation process
仿真过程时间	simulation process time
仿真环境	simulation environment

仿真技术	simulation technique
仿真结果	simulation result
仿真类型	simulation type
仿真模型库	simulation model library
仿真评价	simulation evaluation
仿真器，模拟器，模拟程序	simulator
仿真软件	simulation software
仿真设备	simulation equipment
仿真时钟	simulation clock
仿真实验模式库	simulation experiment mode library
仿真实验室	simulation laboratory
仿真数据库	simulation data base
仿真速度	simulation velocity
仿真算法库	simulation algorithm library
仿真图形库	simulation graphic library
仿真系统	simulation system
仿真信息库	simulation information library
仿真语言	simulation language
仿真运行	simulation run
仿真支持系统	simulation support system
仿真知识库	simulation knowledge base
仿真中断	simulation interrupt
仿真中心	simulation center
仿真专家系统	simulation expert system
仿真作业	simulation job
非调速电气传动	unadjustable speed electric drive
非监督学习	unsupervised learning
分布式控制	distributed control
分类，排序	sort
分类机，分类/排列程序	sorter
分离原理	separation principle
分散控制	decentralized control
分时	time sharing
分时控制	time-sharing control
分支，支路	branch
峰值	peak value
服务系统	service system

浮子液位计	float levelmeter
符号处理	symbol processing
符号模型	symbolic model
符号语言	symbolic language
幅频特性	magnitude/amplitude-frequency characteristics
幅相特性	magnitude-phase characteristics
幅值裕量	magnitude margin
附件	accessory
感觉控制	sensory control
感应继电器	induction relay
隔膜阀	diaphragm valve
根轨迹	root locus
跟踪控制	tracking control
跟踪误差	tracking error
更新	update
工业机器人	industrial robot
工作电压	operating voltage
工作站	work station
工作周期	work cycle
功耗	power consumption/dissipation
功率系数	power factor
谷点电压	valley voltage
故障电流	fault current
惯性的	inertial
光触发晶闸管	light-activated thyristor
光电管	photocell
光符阅读机（OCR）	optical character reader
光扫描器	optical scanner
过程控制	process control
过程自动化	process automation
过渡过程	transient process
过渡过程时间	settling time/transient time
过载	overload
航天遥测	space telemetry
耗散功率	power dissipation
黑箱	black box
厚度传感器	thickness transducer
厚度计	thickness meter/gauge
弧度	radian

缓冲存储器	buffer storage
换向器	commutator
回路电流	loop current
汇［点］	sink
汇编程序	assembler
惠特克-香农采样定理	Whittaker-Shannon sampling theorem
霍尔位移传感器	Hall displacement transducer
击穿电压	breakdown voltage
机器语言	machine language
机械手	manipulator
极限环	limit cycle
集成电路	integrated circuit
集成电路芯片	IC(integrated circuit) chip
计数器	counter
计算机辅助设计工作站	work station for computer aided design
计算机辅助设计软件包	software package of CAD
计算机监控系统	computer supervisory control system
计算机语言	computer language
记录	record, register
记录仪	recorder
记录仪，记录器	logger
技术评价	technical evaluation
加法器	adder
加权法	weighting method
加权函数	weighting function
加权矩阵	weighting matrix
加权因子	weighting factor
价值分析	value analysis
价值工程	value engineering
尖脉冲，窄脉冲	spike pulse
间隙	clearance
监督训练	supervised training
监视器，监督程序	monitor
检流计，电流计	galvanometer
检验位，校验数字	check digit
简化模型	simplified model
键，关键码	key
交流电	alternating current(AC)

阶跃函数	step function
阶跃响应	step response
节流阀，节流圈，扼流	throttle
节流孔，喷嘴	orifice
结构分解	structural decomposition
结构可观测性/结构能观测性	structural observability
结构可控性/结构能控性	structural controllability
结构可通性	structural passability
结构模型	structure model
结构摄动法	structure perturbation approach
结构稳定性	structural stability
结构协调	structural coordination
截止频率	cut-off frequency
解耦子系统	decoupled subsystem
解释	interpret
界面，接口	interface
经典控制理论	classical control system
晶片直径	wafer diameter
静差	steady-state error
静态解耦	static decoupling
静态精［确]度	static accuracy
静态模型	static model
静态特性曲线	static characteristics curve
静态投入产出模型	static input-output model
矩形波逆变器	square/rectangular wave inverter
句法分析	syntactic analysis
句法模式识别	syntactic pattern recognition
锯齿波	sawtooth wave
卡片穿孔机	card punch
卡片阅读机，读卡机	card reader
开关方式变换器	switch-mode converter
开环系统	open loop control
可编程控制	PLC(Programmable Logic Controller)
可变增益/放大系数	variable gain
可变增益法	variable gain method
可测试性	testability
可分性	separability
可控硅	silicon controlled rectifier(SCR)

可理解性	understandability
可稳性	stabilizability
空载	no-load/zero load
控制工程	control engineering
控制精度	control accuracy
控制盘	control panel
控制台	console
控制装置，控制器	control unit
快速恢复二极管	fast recovery diode
宽度计	width meter
框图	block diagram
拉普拉斯变换	Laplace transform
冷却系统	cooling system
离散控制系统	discrete control system
力臂	moment arm
力传感器	force transducer/gauge/sensor
力矩器	torquer
励磁绕组	excitation/exciting/field winding
连续控制系统	continuous control system
量程	span
临界稳定性	critical stability
临界阻尼	critical damping
灵敏度分析	sensitivity analysis
零点	zero
零和对策模型	zero-sum game model
零基预算	zero-based budget
零输入响应	zero-input response
零状态响应	zero-state response
流程图	flow chart/diagram/graph/sheet
流量计	flowmeter
六分仪	sextant
漏电流	leakage current
鲁棒控制	robust control
滤波电路	filter circuit
脉冲发生器	pulse generator
脉动系数	ripple factor
脉宽调制	pulse-width modulation (PWM)

慢变模态	slow mode
慢变状态	slow state
慢变子系统	slow subsystem
密度测量	density measurement
敏感元件	sensing/sensitive element, sensor
铭牌	nameplate
模板库	template base
模板匹配	template matching
模糊控制	fuzzy control
模拟计算机	analog computer
模型参考自适应控制系统	model reference adaptive control system
目标仿真器	target simulator
目的系统	teleological system
逆 Z 变换	inverse z-transform
逆导型晶闸管	reverse-conducting thyristor
耦合	coupling
批处理	batch processing
偏差信号	deviation signal
频分[制]遥测系统	telemetering system of frequency division type
频域分析	frequency domain analysis
平稳随机过程	stationary random/stochastic process
奇异控制	singular control
奇异摄动	singular perturbation
奇异吸引子	singular attractor
奇异线性系统	singular linear system
起动	starting, startup, start
气动的	pneumatic
气关式	air-to-close（AC）
气开式	air-to-open（AO）
前馈控制	feed forward control
前置变换器	pre-converter
欠实时仿真	slower-than-real-time simulation
欠阻尼	underdamping
强耦合系统	strongly coupled system
强制换流	force-commutated
切换点	switching point
切换时间	switching time
清零，清除	clear

趋势法	trend method
趋势分析	trend analysis
权衡分析	trade-off analysis
扰动补偿	disturbance compensation
扰动解耦	disturbance decoupling
热传感器	thermal/heat sensor
热电偶，温差电偶	thermocouple
热交换器	hot exchanger
热交换器，换热器	heat exchanger
人工智能	artificial intelligence(AI)
人机控制	man-machine control
任务分配	task allocation
任务协调	task coordination
任务优化	task optimization
冗余	redundancy
冗余系统	redundant system
软磁盘驱动器	floppy disk drive
软件测试计划	software testing plan
软件测试计划	software testing plan
软件工具	software tool
软约束	soft constraint
润滑剂	lubricant
弱耦合系统	weakly coupled system
三端双向可控硅开关元件	triac
三极真空管	triode
三位控制器	three state/step controller
三重调制遥测系统	triple modulation telemetering system
三轴转台	three-axis table
三轴转台	three-axle table
三轴姿态稳定	three-axis attitude stabilization
上级问题	upper level problem
社会经济系统	socioeconomic system
社会控制论	socio-cybernetics, social cybernetics
射极跟随器	emitter-follower
神经网络	neural network
施塔克尔贝格决策理论	Stackelberg decision theory
湿度测量	humidity measurement
时变参数	time-varying parameter

时变系统	time-varying system
时分[制]遥测系统	telemetering system of time division type
时间比例尺	time scale factor
时间常数	time constant
时间序列分析	time series analysis
时间最优控制，快速控制	time optimal control
时序控制器	time schedule controller
时延	time delay
时域法	time domain method
时域分析	time domain analysis
时域模型降阶法	time domain model reduction method
时滞系统	time delay/time-lag system
时钟，精密计时器	timer
时钟脉冲	clock pulse
实时控制	real time control
示教编程	teaching programming
试运转	test run
受役系统	slaved system
输出	output
输入	input
鼠笼式	squirrel-cage
数据表	data table/sheet/list
数据处理	data processing
数字，数位，位	digit
数字的，数值的	numeric,numerical
数字计算机	digital computer
数字信号处理	digital signal processing
数组，阵列	array
双时标系统	two-time scale system
双稳态电路	bistable circuit
双向开关二极管	diac
顺序分解	sequential decomposition
顺序控制	sequential control
顺序控制器	sequential controller
顺序控制系统/顺控系统	sequential control system
顺序优化	sequential optimization
瞬态偏差	transient deviation
死区	dead band/area/belt/space

伺服/随动控制	servo control
伺服/随动系统	servo
伺服电动机	servomotor
伺服阀	servo valve
伺服控制	servo control
伺服马达/电机	servomotor
速度传感器	velocity transducer
速度传感器	velocity transducer
速度反馈	velocity feedback
速度误差系数	velocity error coefficient
速开阀	quick-opening valve
随动系统，伺服机构	servo
随机存取	random access
随机控制系统	stochastic control system
随机文法	stochastic grammar
随机下推自动机	stochastic pushdown automaton
随机有限自动机	stochastic finite automaton
索引	index
泰勒制	Taylor system
特征轨迹	characteristic locus
梯形图	ladder diagram
跳闸电路	trip circuit
通道，信道	channel
通断控制，开关式/继电器式/双位置控制	on-off control
同步电动机	synchromotor
铜端环	copper end rings
统计控制	statistical control
统计模型识别	statistic pattern recognition
统计预测	statistical forecast/prediction
凸轮	cam
图灵机	Turing machine
图灵实验	Turing test
推力	thrust
推力器	thruster
推力矢量控制系统	thrust vector control system
拓扑结构	topological structure
外围设备	peripheral equipment

完全可观性，完全能观性	complete observability
完全可控性，完全能控性	complete controllability
微调	fine adjustment
维纳滤波	Wiener filtering
温彻斯特磁盘机，硬盘机	Winchester disk drive
温度变送器	temperature transmitter
温度测量仪表	temperature measurement instrument
温度传感器	temperature sensor/transducer
温度计	thermometer
温度开关	temperature switch
温度控制器	temperature controller
稳定 [性]极限	stability limit
稳定 [性]判据/准则	stability criterion
稳定 [性]条件	stability condition
稳定系统	stable system
稳定性分析	stability analysis
稳定性理论	stability theory
稳定域	stable region
稳定裕度/裕量	stability margin
稳态	steady state
稳态偏差	steady state deviation
稳态误差系数	steady state error coefficient
稳态响应	steady state response
稳态值	steady state value
稳压二极管	Zener/voltage stabilizing diode
涡街流量计	vortex shedding flowmeter
涡轮流量计	turbine flowmeter
涡轮式发电机	turbogenerator
无偏估计	unbiased estimation
无源网络	passive network
物位变送器	level transmitter
误差信号	error signal
系统，[最]优化	system optimization
系统辨识	system identification
系统参数	system parameter
系统动力学模型	system dynamics model
系统方法	system approach

系统仿真	system simulation
系统分解	system decomposition
系统工程	system engineering
系统规划	system planning
系统环境	system environment
系统集结	system aggregation
系统建模	system modeling
系统矩阵	system matrix
系统可靠性	system reliability
系统可维护性	system maintainability
系统灵敏度	system sensitivity
系统模型	system model
系统评价	system assessment/evaluation
系统示意图	system diagram
系统同构	system isomorphism
系统同态	system homomorphism
系统统计分析	system statistical analysis
系统误差	system error
系统学	syetematology
系统诊断	system diagnosis
系统状态	system state
显示装置	display unit
现场总线	filed bus
现代控制系统	modern control system
线电压	line voltage
线形时变控制系统	linear time-varying control system
线性定常控制系统	linear time-invariant control system
线性化模型	linearized model
线性控制系统理论	linear control system theory
相似性	similarity
相位控制，相控	phase control
向量李雅普诺夫函数	vector Liapunov function
肖特基二极管	Schottky diodes
效用函数	utility function
效用理论	utility theory
校验位	check digit
校准，标定	calibrate
协同学	synergetics

信号持续时间	signal duration
信号处理	signal processing
信号检测和估计	signal detection and estimation
信号流，[程]图	signal flow diagram
信号选择器	signal selector
信号重构	signal reconstruction
信号转换器	signal converter
信息，报文	message
序贯最小二乘估计	sequential least squares estimation
序列，顺序	sequence
旋进流量计	swirlmeter, vortex precession flowmeter
旋转变压器	rotating transformer, revolver
训练仿真器	training simulator
压力表	pressure gauge
压力计	manometer
遥测	telemetry, remote measurement/ metering/test
遥测通信系统	telemetering communication system
遥控	remote control, telecontrol
遥控力学/远动学	telemechanics
遥控系统	remote control/telecontrol system
液压控制	hydraulic control
一致渐近稳定性	uniformly asymptotic stability
一致稳定性	uniform stability
仪表板/控制板	dash panel
移位，移数	shift
役使原理，从属原理	slaving principle
溢出，上溢	overflow
印制电路	printed circuit
应变计，应变片	strain gage
应变式称重传感器	strain gauge load cell
用户友好界面	user-friendly interface
游丝，细测量线	hairspring
有源网络	active network
语义网络	semantic network
语音识别	speech recognition
源[点]	source
远程通信	telecommunication

运算放大器	op-amp(operational amplifier)
杂散电感，漏电感	stray inductance
再生发电制动	regenerative braking
暂态特性曲线	transient process characteristic curve
闸流管	thyratron
闸流晶体管/可控硅	thyristor
黏性阻尼	viscous damping
占空比	duty ratio
张力计	tensiometer, tonometer
真空管，电子管	vacuum tube
振动传感器	vibration transducer
振动计	vibrometer
振弦式力传感器	vibrating wire force transducer
镇定，稳定	stabilization
镇定网络	stabilizing network
正反馈	positive feedback
正偏	forward/positive biased
正偏压	forward/positive bias
正弦波	sine/sinusoidal wave
正向通道	forward path/channel
直接数字控制，DDC	direct digital control
指令	instruction
指令，命令	command
制表机	tabulator
治疗模型	therapy model
智能控制器	intelligent control
智能仪表	intelligent instrument
中间抽头变压器	center-tapped transformer
终端控制	terminal control
终端设备，终端	terminal unit
轴	axis
轴承	bearing
逐步精化	stepwise refinement
主观概率	subjective probability
专家系统	expert system
转换文法	transformation grammar
转矩，扭矩	torque

转矩传感器	torque transducer
转速表	tachometer
转移图	transition diagram
转子，电枢	rotor
转子流量计，浮子流量计	rotameter
装入，加载	load
状态变量	state variable
状态变量变换	transformation of state variable
状态反馈	state feedback
状态方程模型	state equation model
状态估计	state estimation
状态观测器	state observer
状态轨迹	state trajectory
状态空间法	state space method
状态空间描述	state space description
状态图	state diagram
状态向量	state vector
状态约束	state constraint
状态转移矩阵	state transition matrix
状态转移模型	state transition model
子程序	subroutine, subprogram
子系统	subsystem
字节，八位位组	octet, byte
字母数字的	alphanumeric
自持振荡	sustained oscillation
自动控制系统	automatic control system
自耦变压器	autotransformer
自上而下测试	top-down testing
自上而下开发	top-down development
自校正控制	self-tuning control
纵向分解	vertical decomposition
阻抗	impedance, resistance
阻尼比	damping ratio
阻尼系数	damping coefficient/factor
阻尼线圈	damper/damping coil
阻尼振荡	damped/dying oscillation
钻床	drill, drilling machine, driller
最短路径问题	shortest path problem

最佳优先搜索	best-first search
最小相位系统	minimum phase system
最优控制系统	optimal control system
作业程序	task program
作业级语言	task level language
作业空间	working space
作业周期	task cycle

附录 2　中英文课程对照

BASIC 语言	Basic Language
C 语言	C Language
C++程序设计与训练	C++ Program Design and Training
CIMS 概论	Introduction to Computer-integrated Manufacturing System
EDA 技术基础	Fundamentals of EDA Technology
IBM-PC 微机原理	Principles of Microcomputer IBM-PC
Java 程序设计与训练	Java Program Design and Training
Unix 操作系统分析	Analysis of Unix Operating System
VLSI 设计基础	Fundamentals of Very Large Scale Integration Design
办公自动化	Office Automation
半导体变流技术	Semiconductor Converting Technology
半导体光电子学	Semiconductor Optoelectronics
半导体器件与集成电路	Semiconductor Devices and Integrated Circuits
半导体物理	Semiconductor Physics
毕业论文	Graduation Thesis
毕业设计	Graduation Design
毕业实习	Graduation Practice
编码与信息理论	Coding and Information Theory
编译原理	Principles of Compiling
变电站微机检测与控制	Microcomputer Testing & Control in Transformer Substation
变频器设计与应用	The Design and Applications of Inverters
并行算法	Parallel Algorithm
材料力学	Mechanics of Materials
操作系统原理	Principles of Operating System
测量原理与仪器设计	Measurement Principles & Instrument Design
测试技术	Testing Technology
常微分方程	Ordinary Differential Equations
超大规模集成电路与系统	VLSI Circuits and Systems
程控数字交换	SPC Digital Exchange

程序设计基础	Fundamentals of Programming
程序设计语言	Programming Language
传感器理论与设计	Theory and Design of Transducers
传感器与检测技术	Sensors & Testing Technology
传感器原理及应用	Principles & Applications of Sensors
船舶电气传动自动化	Ship Electric Drive Automation
磁测量技术	Magnetic Measurement Technology
大型火电机组控制	Control of Large Thermal Power Generator Networks
大学物理	College Physics
大学物理实验	Experiment of College Physics
大学英语	College English
代数几何	Algebraic Geometry
单片机原理及应用	Principles & Applications of Microcontrollers
单片机原理与接口技术	Microcontrollers Principles & Interface Technology
低频电子线路	Low Frequency Electronic Circuits
低温传热学	Cryogenic Conduction
低噪声电子电路	Low-noise Electronic Circuits
电厂故障诊断与分析	Fault Diagnosis and Analysis for Power Stations
电厂计算机控制系统	Computer Control System in Power Plants
电厂计算机实时控制系统	Computer Real-time Control System in Power Plants
电磁场理论	Theory of Electromagnetic Fields
电磁场数值分析	Numerical Analysis of Electromagnetic Fields
电磁场与电磁波	Electromagnetic Fields & Electromagnetic Waves
电磁场与微波技术	Electromagnetic Fields & Microwave Technology
电磁场中的数值方法	Numerical Methods in Electromagnetic Fields
电磁学	Electromagnetics
电工测量技术基础	Measurement Technology Fundamentals of Electrical Engineering
电工电子技术基础	Fundamentals of Electrical Engineering & Electronic Technology
电工电子学	Electrical Engineering and Electronics
电工基础	Fundamentals of Electrical Engineering
电工基础实验	Experiment in Electrical Engineering
电工技术	Electrotechnics
电工技术基础	Fundamentals of Electrotechnics
电工学	Electrical Engineering (Electrotechnics)
电工与电机控制	Electrical Engineering & Motor Control

电机测试技术	Motor Measuring Technology
电机电磁场	Electromagnetic Field in Electric Machines
电机电器与供电	Motor Elements and Power Supply
电机课程设计	Curriculum Project in Electric Machines
电机绕组理论及应用	Theory & Applications of Motor Winding
电机设计	Design of Electric Motors
电机学	Electric Motors
电机与拖动	Electric Machinery & Towage
电机原理与拖动	Principles & Towage of Electric Machinery
电力电子电路	Power Electronic Circuits
电力电子基础	Fundamentals of Power Electronics
电力电子器件	Power Electronic Devices
电力电子学	Power Electronics
电力工程	Electric Power Engineering
电力拖动	Electric Drive
电力拖动基础	Fundamentals of Electric Towage
电力拖动控制系统	Electric Towage Control Systems
电力拖动与电气控制	Electric Towage & Electrical Control
电力系统分析	Power Systems Analysis
电力系统规划	Power Systems Planning
电力系统基础	Fundamentals of Power Systems
电力系统继电保护	Power Systems Relay Protection
电力系统优化设计	Optimal Design of Power Systems
电力系统暂态分析	Power Systems Transient Analysis
电力系统自动化	Automation of Electric Systems
电力系统自动装置	Automation Equipments of Power Systems
电路测试技术	Circuit Measurement Technology
电路分析基础	Fundamentals of Circuit Analysis
电路分析实验	Circuit Analysis Experiments
电路理论基础	Fundamentals of Circuit Theory
电路原理	Principles of Circuits
电路原理实验	Laboratory in Principles of Circuits
电气测量技术	Electrical Measurement Technology
电气传动与运动控制系统	Electric Drive and Motion Control System
电气控制技术	Electrical Control Technology
电气控制与 PLC 应用	Electrical Control and Application of PLC
电气伺服系统设计与应用	The Design and Applications of Electric Servo Systems

电器设计	Electrical Appliances Design
电器学	Electrical Appliances
电器与控制	Electrical Appliances & Control
电视接收技术	Television Reception Technology
电视原理	Principles of Television
电网调度自动化	Automation of Electric Network Management
电影艺术	Art of Film Making
电子材料与元件	Electronic Materials and Elements
电子工艺实习	Electronic Working Technology Practice
电子技术课程设计	Curriculum Project in Electronic Technology
电子商务	Electronic Commerce
电子线路计算机辅助分析	Computer Aided Analysis of Electronic Circuits
电子线路实验	Laboratory in Electronic Circuits
多媒体计算机技术	Multimedia Computer Technology
二阶线性偏微分方程	Linear Second Order Partial Differential Equation
发电厂电气部分与热力设备	Electric Elements & Thermodynamics Equipments of Power Plants
发电厂热力过程仿真技术	Simulating Technology for Process of Power Plants
发电厂热力设备的优化运行	Optimal Operation for Thermoelectric Power Stations
法律基础	Fundamentals of Law
泛函分析	Functional Analysis
非线性电路理论	Nonlinear Circuit Theory
非线性动力系统	Nonlinear Dynamical Systems
非线性方程组数值解法	Numerical Methods of Nonlinear Equation Systems
非线性控制理论	Nonlinear Control Theory
非线性控制系统	Nonlinear Control Systems
分布式计算机控制系统	Distributed Computer Control Systems
复变函数与积分变换	Complex Function and Integral Transform
概率论与数理统计	Probability Theory and Mathematics Statistics
概率与统计	Probability and Statistics
高等代数与几何	Advanced Algebra and Geometry
高等数理统计	Advanced Mathematical Statistics
高等数学	Higher Mathematics
高电压测量技术	High Voltage Measuring Technology
高电压技术与设备	High Voltage Technology and Devices
高电压绝缘	High Voltage Insulation
高压电工程	High-voltage Engineering
工厂供电	Power Supply in Factory

工程测量实习	Engineering Measuring Practice
工程计算机图形学	Engineering Computer Graphics
工程数学	Engineering Mathematics
工程制图基础	Fundamentals of Engineering Drawings
工业工程	Industrial Engineering
工业设计与信息技术	Industry Design and Information Technology (ID&IT)
功能材料与微电子技术	Functional Material & Microelectronic Technology
固态电子学	Solid State Electronics
故障诊断与容错技术	Fault Diagnosis & Fault Tolerance Technology
管理信息系统	Management Information System (MIS)
管理学	Management
光电探测及信号处理	Photoelectric detect & Signal Processing
光电子技术	Photoelectronic Technology
光纤传输理论与系统	Optical Fiber Communication Theory and Systems
光纤通信技术	Fiber Optic Communication Technology
光纤通信网络	Networks of Fiber Communications
光纤通信系统	Systems of Fiber Communications
过程控制调节装置	Process Control & Regulation Equipments
过程控制工程	Process Control Engineering
红外器件与红外技术	Infrared Devices and Infrared Technology
汇编语言程序设计	Assembly Language Programming
货币银行学	Monetary and Bank
机床电气	Machine Tool Electric
机床自动化	Automation of Machine Tool
机电系统 CAD 导论	Introduction of CAD for Mechatronic Systems
机电系统电液控制	Electro-Hydraulic Control for Mechatronic Systems
机器人控制	Robot Control
机械零件课程设计	Curriculum Project of Machinery Parts
机械制图	Machine Drawing
计算方法	Numerical Methods
计算机仿真	Computer Simulation
计算机辅助工业设计	Computer Aided Industry Design
计算机辅助设计	Computer Aided Design
计算机汇编语言	Computer Assembly Language
计算机基础	Foundations of Computer
计算机控制技术	Computer Control Technology
计算机控制系统设计	Design of Computer Control Systems
计算机软件基础	Foundations of Computer Software

计算机实时控制系统	Computer Real-time Control Systems
计算机视觉	Computer Vision
计算机数据安全	Computer Data Security
计算机图形学	Computer Graphics
计算机网络与分布式处理	Computer Networks & Distributed Processing
计算机网络与数据通信	Computer Networks & Data Communication
计算机网络与应用	Computer Networks and Applications
计算机语言处理	Computer Language Processing
计算机语言与程序设计	Computer Languages and Programming
计算机组成原理	Principles of Computer Composition
检测技术及自动化仪表	Detection Technology & Automatic Instruments
检测与显示技术	Detection & Display Technology
交流电机调速理论	Theory of Speed Adjusting of Alternating Current Motors
教学理论与实践	Teaching Theories and Methodology
金工实习	Metalworking Practice
金属腐蚀与应用	Metal Erosion & Applications
金属工艺及设计	Metal Technics & Design
精密电磁测量	Precise Electromagnetic Measurement
矩阵分析	Matrix Analysis
决策分析	Analysis of Policy Making
科技翻译	Scientific English Translation
科技史	History of Science & Technology
科技文献检索	Scientific Document Retrieve
科技英语	Scientific English
科技英语阅读	Readings of Scientific English
科学技术史	History of Science & Technology
科学社会主义理论与实践	The Theory and Practice of The Scientific Socialism
科学思想史	History of Scientific Thoughts
可编程控制器原理与应用	The Principles of Programmable Controller and Its Applications
可靠性及故障诊断	Reliability & Fault Diagnosis
可靠性与优化设计	Reliability & Optimization Design
课程设计	Curriculum Project
空气调节与通风	Air Regulation & Ventilation
控制电机	Electrical Machines for Control
控制工程	Control Engineering
控制工程基础	Foundations of Control Engineering

控制理论基础	Foundations of Control Theory
控制系统数字仿真与 CAD	Digital Simulation of Control Systems & CAD
口语训练	Oral Training
离散数学	Discrete Mathematics
理论力学	Theoretical Mechanics
量子力学	Quantum Mechanics
流体传动及控制	Fluid Transmission and Control
论文写作	Thesis Writing
论文选读	Study on Selected Papers
脉冲与数字电路	Pulse & Digital Circuits
面向对象程序设计	Object-Oriented Programming
面向对象软件技术	Object-Oriented Software Technology
敏感元件及材料	Sensors & Materials
模糊数学	Fuzzy Mathematics
模糊数学及其工程应用	Fuzzy Mathematics and its Engineering Applications
模拟电子技术	Analog Electronics Technology
模拟电子技术基础	Fundamentals of Analog Electronics
模拟电子线路	Analog Electronic Circuits
模拟集成电路分析与设计	Analysis and Design of Analog Integrated Circuits
模拟集成电路及应用	Analog Integrated Circuits & Applications
模式识别	Pattern Recognition
内燃机调节	Internal-Combustion Engine Regulation
内燃机检测技术	Measuring Technology for Internal-Combustion Engine
能源工程	Energy Engineering
偏微分方程	Partial Differential Equation
普通化学	General Chemistry
普通物理	General Physics
气压传动	Pneumatic Transmission
汽轮机调节与仿真	Adjustment & Simulation of Steam Turbines
嵌入式系统	Embedded Systems
切削原理及刀具	Metal Cutting Principles & Tools
情报检索	Information Retrieve
热处理原理及工艺	Principles & Technology for Heating Processing
热工测量及仪表	Thermal Measurement & Meter
热工过程自动调节	Automatic Adjustment of Thermal Process
热力发电厂	Thermal Power Stations
热力学	Thermodynamics
人工智能及应用	Artificial Intelligence and Its Applications

人工智能与机器人	Artificial Intelligence and Robot
容错与诊断	Tolerance & Diagnosis
柔性制造技术	Flexible Manufacturing Technology
软件测试技术	Software Testing Technology
软件工程	Software Engineering
软件技术基础	Foundations of Software Technology
软件开发工具与环境	Tools & Environment for Software Developing
弱信号检测	Testing of Feeble Signals
商务英语	Business Affairs English
生产过程计算机控制	Computer Control in Manufacturing Process
生产实习	Production Practice
时间序列与动态数据处理	Time Series and Dynamic Data Processing
实变函数与泛函分析	Functions of Real Variable & Functional Analysis
数据采集系统与接口技术	Data Acquisition Systems and Interface Technology
数据结构	Data Structure
数据结构课程设计	Curriculum Project of Data Structure
数据库概论	Introduction to Database
数据库管理系统概论	Introduction to Database Management System
数据库基础	Foundations of Database
数据库技术与应用	Technology & Applications of Database
数据库原理及应用	Principles & Applications of Database
数控机床	Digital Control Machine Tool
数控技术	Digital Control Techniques
数理方程	Mathematics and Physical Equations
数理逻辑	Mathematical Logic
数理统计及应用	Mathematical Statistics & Applications
数学分析	Mathematical Analysis
数学物理方法	Methods of Mathematical Physics
数值分析	Numerical Analysis
数值计算	Numerical Computation
数字测量技术	Digital Measuring Techniques
数字电路	Digital Circuits
数字电视	Digital Television
数字电子技术	Digital Electronic Techniques
数字电子技术基础	Fundamentals of Digital Electronic Techniques
数字电子技术设计与实验	Design & Experiment of Digital Electronic Techniques
数字电子线路	Digital Electronic Circuits
数字仿真	Digital Simulation

数字化测量技术	Digital Measuring Techniques
数字集成电路设计	Digital Integrated Circuit Design
数字逻辑电路	Digital Logic Circuits
数字逻辑课程设计	Curriculum Project of Digital Logic
数字逻辑设计	Digital Logic Design
数字通信与系统	Digital Communication and Systems
数字图像处理	Digital Image Processing
数字系统的故障诊断	Fault Diagnosis of Digital Systems
数字系统逻辑设计	Logical Design of Digital Systems
数字系统设计	Design of Digital Systems
数字信号处理	Digital Signal Processing
数字语音处理	Digital Voice Processing
水电站计算机控制	Computer Control in Hydropower Station
水电站自动化	Automation of Hydropower Station
水轮机调节	Regulations of Water-turbine Engine
算法设计与分析	Algorithmic Design & Analysis
随机过程	Stochastic Processes
锁相技术	Phase-locked Techniques
听说训练	Practice on Listening & Speaking
通信原理概论	Introduction to Principles of Communications
通信原理与技术	Principles & Technology of Communication
图像处理与计算机视觉	Image Processing and Computer Vision
托福考试	Test of English as a Foreign Language
外贸函电	Foreign Business Correspondence
外贸英语	Foreign Business English
网络理论	Electrical Network Theory
微波技术与天线	Microwave Techniques and Antenna
微波器件及电路	Microwave Devices and Circuits
微波通信	Microwave Communication
微波遥感	Microwave Remote Sensing
微电子学概论	Introduction to Microelectronics
微分方程数值解	Numerical Methods for Differential Equations
微分几何	Differential Geometry
微机化仪表设计	Design of Microcomputer-based Instrumentation
微机继电保护基础	Foundations of Computer Relay Protection
微机控制系统	Control Systems of Microcomputer
微机励磁控制系统	Magnetic Excitation Control Systems of Microcomputer
微机系统与接口	Microcomputer Systems and Interface
微机原理及接口技术	Principles & Interface Techniques of Microcomputer
微机原理及应用	Principles & Applications of Microcomputer

微积分	Calculus
微型机及应用	Microcomputer & Its Applications
微型计算机控制技术	Microcomputer Control Techniques
卫星通信	Satellite Communications
文献检索	Document Retrieve
无线电系统与设备	Radio Systems & Equipments
物理化学	Physics Chemistry
误差理论	Theory of Error
系统辨识	System Discrimination
先进控制技术	Advanced Control Technology
显示技术及装置	Display Techniques & Equipment
显示仪表	Display Instrument
现代测试技术	Modern Testing Technology
现代传感技术	Modern Sensing Technology
现代控制理论与应用	Modern Control Theory and Applications
现代企业管理	Modern Enterprise Administration
现代通信理论与技术	Emerging Communications Theory and Technology
现代通信原理	Principles of Modern Communications
现代仪器分析	Modern Instrumental Analysis
线性代数	Linear Algebra
线性代数与解析几何	Linear Algebra and Analytic Geometry
线性规划	Linear Programming
线性系统理论	Theory of Linear Systems
相对论	Principles of Relativity
小波分析及工程应用	Wavelet Analysis and Its Applications in Engineering
信道编码理论与技术	Channel Coding Theory and Technology
信号与系统	Signals and Systems
信号与线性系统	Signal & Linear Systems
信息论基础	Fundamentals of Information Theory
信息论与编码	Information Theory & Coding
形势与教育	Situation & Education
形势与政策	Situation & Policy
虚拟仪器与应用	Virtual Instruments and Application
遥感技术	Remote Sensing Techniques
液压传动	Hydraulic Transmission
液压系统数字仿真	Digital Simulation in Hydraulic Systems
液压元件	Hydraulic Elements
仪器电路设计	Instrument Circuit Design
仪器分析	Instrumental Analysis
仪器分析实验	Instrumental Analysis Experiment

移动通信	Mobile Communication
应用概率统计	Applied Probability and Statistics
英汉翻译	English-Chinese Translation
英汉口译	English-Chinese Oral Interpretation
英语听说训练	English Practice on Listening & Speaking
英语专题研究	English Special Research
语音信号处理	Speech Signal Processing
运筹学	Operational Research (Operations Research)
直流调速系统	Direct Current Governor Systems
直流输电	Direct Current Transmission
制冷与空调	Refrigeration & Air-conditioning
制冷原理与设备	Refrigeration Principles & Equipments
智能测试仪器与系统	Intelligent Testing Instruments and Systems
智能检测原理与技术	Intelligent Testing Principles and Technology
智能控制理论及应用	Intelligent Control Theory and Applications
智能仪器设计与应用	Design & Applications of Intelligent Instrument
铸造机械设备	Casting Equipment of Machine
铸造新工艺	New Casting Techniques
专家系统	Expert Systems
专利文献检索	The Retrieve of Patent Documents
专业课	Specialized Courses
专业课程设计	Course Project in Speciality Fields
专业实习	Practice of Speciality
专业文献综述	Review on Special Information
专业英语	Scientific English
自动测试系统	Automatic test Systems
自动化系统故障诊断	Fault Diagnosis of Automation Systems
自动检测技术与仪表	Automatic Measurement Techniques & Meters
自动控制理论	Theory of Automatic Control
自动控制元件	Automatic Control Component
自动控制原理	Principles of Automatic Control
自动显示仪表	Meter of Automatic Display
自然科学概论	Introduction to Natural Science
自适应控制	Self-adapting Control
自适应控制与鲁棒控制	Adaptive Control and Robust Control
组合数学	Combinatorial Mathematics
最优方法及应用	Optimization Methods and Its Applications
最优化及最优控制	Optimization and Optimal Control

附录 3　单 位 换 算

3.1　Metric System

3.1.1　Length

micron (u) (微米)	=1/1,000,000(米)
centimillimetre(cmm) (忽米)	=1/100,000(米)
decimillimetre(dmm) (丝米)	=1/10,000(米)
millimeter(mm)(毫米)	=1/1,000(米)
centimeter(cm) (厘米)	=1/100(米)
decimeter(dm) (分米)	=1/10(米)
meter (m) (米)	=1m(米)
decameter(dam) (十米)	=10m(米的十倍)
hectometer(hm) (百米)	=100m(米的百倍)
kilometer(km) (千米)	=1000m(米的千倍)

3.1.2　Area

square millimeter (平方毫米)	=1/1,000,000(平方米)
square centimeter(平方厘米)	=1/10,000(平方米)
square decimeter(平方分米)	=1/100(平方米)
square meter (平方米)	=1(平方米)
square decameter(百平方米)	=100(平方米)
square hectometer(万平方米)	=1/100(平方千米)
square kilometer(平方千米)	=1(平方千米)
square meter(平方米)	=1 centiare(千米)
centiare (ca) (千米)	=1/100 are(公亩)
are (a) (公亩)	=1/100 hectare(公顷)
hectare (ha) (公顷)	100 are(公亩)

3.1.3　Volume

cubic millimeter(立方毫米)	=1/1,000 (立方厘米)
cubic centimeter(立方厘米)	=1/1,000(立方分米)
cubic decimeter(立方分米)	=1/1,000(立方米)
cubic meter(立方米)	=1(立方米)

3.1.4 Capacity

milliliter(ml) (毫升)	=1/1,000(升)
centiliter(cl) (厘升)	=1/100(升)
deciliter(dl) (分升)	=1/10(升)
litre (1) (升)	=1(升)
decalitre (dal) (十升)	=10(升)
hectoliter (hl) (百升)	=100(升)
kilolitre (kl) (千升)	=1,000(升)

3.1.5 Weight

milligramme (mg) (毫克)	=1/1,000g(克)
centigramme (dg) (厘克)	=1/100g(克)
decigramme (dg) (分克)	=1/10g(克)
gramme (g) (克)	=1g (克)
decagramme (dag) (十克)	=10g (克)
hectogramme (hg) (百克)	=100g(克)
kilogramme (kg) (千克)	=1000g(克)
quintal (q) (公担)	=100kg (千克)
metric ton (M.T.) , tonne (t) (公吨)	=1,000kg(千克)

3.2 Chinese System

3.2.1 Length

1 chi(市尺)	=10 cun(市寸)
1 zhang(市丈)	=10 chi(市尺)
1 li(里)	=150 zhang(丈)

3.2.2 Are

1 square li (平方里)	=375mu(亩)

3.2.3 Capacity

1 dou(斗)	=10 sheng(升)
1 dan (石)	=10 dou(斗)

3.2.4 Weight

1 liang(两)	=10 qian(钱)
1 jin(斤)	=10 liang(两)
1 dan(担)	=100 jin(斤)

3.3　Anglo-American System

3.3.1　Length

1 mil(密耳)	=1/1000 in(英寸)
12 inches(英寸) (in.)	=1 foot(fl.) (英尺)
3 feet(英尺)	=1 yard (yd.) (码)
5 1/2 yard(码)	=1 rod(rd.) (杆) 或 pole(p.) 或 porch(p.)
40 rod(杆)	=1 furlong(fur.) (浪)
8 furlong(浪)	=1 mile(m.or.mi) (英里)
3 miles(英里)	=1 land league (里格)

3.3.2　Chain

144 square inches (sq.in.) (平方英寸)	=1 square foot(sq.ft) (平方英尺)
9 square feet(平方英尺)	=1 square yards(sq.yad.) (平方码)
30 1/4 square yards(平方码)	=1square rod(sq.rd.) (平方杆) 或 square pole 或 square porch(sq.p.)
43,560 square feet(平方英尺) or 160 square rods(平方杆) or 4,840 square yards(平方码)	=1 acre (A.) (英亩)
circular mil 圆密尔(直径为 1 密耳的圆面积，用作英制电线粗细的量度)	
625 square lingks (sq.li.) (平方令)	=1 square pole(sq.p.) (平方杆)
16 square poles(平方杆)	=1 square chain(sq.ch.) (平方链)
10 square chains(平方链)	=1 acre(A.) (英亩)
640 arce(英亩)	= 1 square mile(sq.mi.) (平方英里) 或 1 section(sec.) (段)
56 square miles(平方英里)	=1 township(tp.) (区)

3.3.3　Volume

1,728 cubic inches (cu.in.) (立方英寸)	=1 cubic foot(cu.ft) (立方英尺)
27 cubic feet(立方英尺)	=1 cubic yard (cu.yd.) (立方码)

3.3.4　Nautical Measure

6 feet (英尺)	=1 fathom (f. fm.) (英寻)
100 fathoms(英寻)	=1 cable's length(链)
10 cable's lengths(链)	=1 nautical mile(海里)
3 nautical miles(海里)	=1 marine league (水程里格)
60 nautical miles(海里)	=1 degree(度)

附录 4　度量衡比较表

4.1　Length

Metric System	Chinese System	Anglo-American System
1 meter(或 m) (米)	=3 chi(市尺)	=1.0936 yd.(码)
10 meters	=3 zhang(市丈)	=10.936(码)
1 kilometer(或 KM) (千米化)	=2 li(市里)	=1,039.6(码)

Chinese System	Metric System	Anglo-American system
1 chi(市尺)	=1/3meter(米)	=1.0936 ft.(英尺)
1 li(市里)	=0.5 kilometer(千米)	=0.3107 mile.(英里)

Anglo-American system	Metric System	Chinese System
1 in.(英寸)	=2.54 cm(厘米)	=0.762 cun(市寸)
1 ft.(英尺)	=0.3804 m(米)	=0.9144 chi(市尺)
1 yd.(码)	=0.9144 m(米)	=2.7432 chi(市尺)
1 mi.(英里)	=1.6093 km(千米)	=3.2187 li(市里)

4.2　Area

Metric System	Chinese System	Anglo-American System
1 square meter(平方米)	=9sq.chi(平方尺)	=1.196 sq.yd.(平方码)
1 are(公亩)	=900 sq.chi(平方尺)	=119.6 sq.yd.(平方码)
1 square kilometer(平方千米)	=4 sq. li(平方里)	=0.386 sq.yd.(平方英里)
1 hectare (ha) (公顷)	=15 mu(亩)	=2.471 acres.(英亩)
Chinese System	Metric System	Anglo-American System
1mu (亩)	=1/15 hectare(公顷)	=0.1644 acre(英亩)

Anglo-American system	Metric System
1 sq.in.(平方英寸)	=6.452(平方厘米)
1 sq.ft.(平方英尺)	=929(平方厘米)
1 sq.yd.(平方码)	=0.8361(平方米)

Anglo-American System	Chinese System	Metric System
1 acre (英亩)	=6.07mu(亩)	=40.4687 ares(公亩)
640 acre(英亩)	=10.36 sq.li(平方里)	=2.59　km(平方千米)
1 sq.mi.(平方米)		=2.59　km(平方千米)
1 township(区)		=93.24 km(平方千米)

4.3　Capacity

Metric System	Chinese System	Anglo-American System
1 decilitre(分升)	=1 he(市合)	
1 litre（升）	=1 sheng（升）	=0.264 U.S.gallon(美制加仑) =0.22 British gallon(英制加仑) =0.9081 dry quart(干量夸脱) =1.0567 liquid quart(液量夸脱)
10 litres（升）	=1 dou(市斗)	
100 litres（升）	=1 dan(市石)	=2.838 bushels(蒲式耳) =26.418 gallon(加仑)

4.4　Weight

Metric System	Chinese System	Anglo-American System
1 gram(克)	=2 fen(分)	=0.0355 oz.(英两)
100 gram(克)	=2 liang(两)	=3.55 oz.(英两)
1 kilometer (千克)	=2 jin(斤)	=2.2046 lb(磅)
1 quintal (公担)	=2 dan(担)	=220.46 lb.(磅)
Chinese System	Metric System	Anglo-American system
1 liang(两)	=50 grams(克)	=1.7657 oz.(英两)
1 jin(斤)	=0.5kg(千克)	=1.1023 oz.(英两)
1 dan(担)	=50 kg(千克)	=0.0492 long ton (英吨) =0.0551 short ton(美吨)

Anglo-American System	Metric System
1 lb.(磅)	=0.4536 kg.(千克)
1 short ton(美吨)	=0.90718 metric ton (公吨)
1 long ton(英吨)	=1.120 short ton(美吨)

4.5　Density

1 g. per cu.com.(克/立方厘米)	=0.03613 lb. per cu.in.(磅/立方英寸)
1 kg. per cu.meter(千克/立方米)	=0.06243 lb. per cu.cm.(磅/立方英尺)
1 lb. per cu. in(磅/立方英寸)	=27.680 g. per cu.cm(克/立方厘米)
1 lb.per cu.ft(磅/立方英尺)	=16.081 kg. per cu. meter(千克/立方米)

4.6　Force

1,000,000 dynes(达因)	=2.2481 lb.(磅)	=1.020 kg.(千克)
1 kg.(千克)	=2.2046 lb.(磅)	=980,655 dynes(达因)
1 lb.(磅)	=0.4536kg.(千克)	=444,822(达因)

4.7　Pressure

1 bar(巴)	=10 的 6 次方达因/平方厘米
1 ft. of water(英尺水)	=62.4 lb. per sq.ft.(磅/平方英尺) =0.433 lb. per sq. in.(磅/平方英尺)
1 in. of mercury(英寸汞)	=1.134 ft. of water(英尺水) =0.4912 lb.per sq. in.(磅/每平方英寸)
1 atmosphere (大气压)	=1.013 巴=1,013 毫巴 =14.697 lb. per sq. in.(磅/平方英寸) =33.9 ft. of water(英尺水)
1 lb. per sq. ft.(磅/平方英尺)	=4.8824 kg. per sq. m(千克/平方米)
1 lb. per sq. in.(磅/平方英尺)	=0.07031 kg. per sq. cm.(千克/平方厘米)
1 kg. per sq. cm.(千克/平方厘米)	=14.223 lb. per sq. in(磅/平方英寸) =32.8 ft.of water(英尺水)
1 ton per sq.ft.(吨/平方英尺)	=13.889lb.per sq. in.(磅/平方英寸)

4.8　Energy

1 ft.-lb(英尺.磅)	=1,356joules(焦耳) 或 watt-sec.(瓦特.秒)
1 joule(焦耳)	=10（的 7 次方) ergs() =10 dyne-cm()
1 horse-power-hr.(英制马力.小时)	=1.98*10(对次方) ft. -lb.(英尺磅) =0.7457 kw-hr.(千瓦.时) =2.544 btu. (英国)

1 kw-hr.(千瓦.时)	=1.341horse-power-hr.(马力小时) =3.411 btu.(英国热单位) =2.654*10(的 6 次方) ft.-lb(英尺磅)
1 btu.(英国热单位)	=778.4ft.-lb.(英尺磅) =0.252 kcal.(千卡)
1 meter-kilometer(米.千克)	=7.233ft.-lb.(英尺磅)

4.9　power

1 horse-power(马力)	=33.000 ft. -lb. per min.(英尺.磅/分) =550 ft.-lb.persec.(英尺.磅/秒) =0.7457 kw.(千瓦) =0.7066 Btu.per-sc(英国热单位/秒)
1 kw.(千克)	=1.341 h.p.(英制马力) =737.5 ft.-lb. per sec.(英尺.磅/秒)
1 horse-power	=1.0139 metric horse-power (公制马力)

4.10　Speed

1 rad.per sec.(弧度/秒)	=9.5496rev.per min(转数/分) =0.15916 rev.per sec.(转数/秒）
1 rev.per min(转数/分)	=6 deg.per sec(度/秒)
1 ft.per sec.(英尺/秒)	=0.6818mile per hr.(英里/时)
1 mile per hr.(英里/时)	=83 ft.per min.(英尺/分)
1 mile per hr.(英里/时)	=83 ft. per min.(英尺/分) =1.4467 ft.per sec.(英尺/秒)

4.11　Circle

1 circle(圆周)	=4 quadrants(象限)
1 quadrant(象限)	=90 degree(*) (度)
1 degree(*) (度)	=60 minutes(') (分)
1 minute(') (分)	=60 second('') (秒)
1 rad.(弧度)	=1/2p circle(圆周) =57.2958 deg.(度) =3,437.75 min.(分) =206,265 sec.(秒)

4.12　Temperature

nC(摄氏度数)	=(n*1.8) +32(华氏度数)
mF(华氏度数)	=(m-32) *5/9(摄氏度数)

附录 5　常用数学符号

Commonly-used Mathematic Symbol

0.4	zero (或 nought) point four	
0.01	point (或 decimal) nought one	
10.34	ten point three four	
$\sqrt{49}$	the square (或 second) root of forty-nine	
$\sqrt[3]{120}$	the cube (或 third) root of	
10×8 feet	ten by eight feet(意为：十英尺长八英尺宽)	
$\approx$	be congruent with; approximately equal	近似于
$\sim$	equivalent	相当于
Π=3.1415926536…	the ratio of the circumference of a circle to the diameter	圆周率
e=2.7182818285	the base of natural logarithm	自然对数的底
∞	infinity	无穷大
$i=\sqrt{-1}$	the unit of imaginary numbers	虚数单位
$n!$	the factorial of n	N 的阶乘
$[x]$	the greatest integer not greater than x	不大于 x 的最大整数
$\propto$	varies directly as	正比于
$\lg a$, $\log_{10} a$	common logarithm	常用对数
$\ln a$, $\log_e a$	natural logarithm	自然对数
(a, b)	the open interval $a<x<b$	开区间
$[a, b]$	the closed interval $a\leqslant x\leqslant b$	闭区间
$(a, b]$	the interval $a\leqslant x<b$	半开区间
$[a, b)$	the interval $a<x\leqslant b$	半开区间
$\sum\limits_{i=1}^{n}, \sum\limits_{1}^{n}$	sum to n terms	n 项的和
$\prod\limits_{i=1}^{n}, \prod\limits_{1}^{n}$	product of n terms	n 项的积
lim sup ,lim	superior limit	上极限
lim inf ,$\underline{\lim}$	inferior limit	下极限
$f(x)$	the function of x	x 的函数

$\lim\limits_{x\to a} f(x)$	the limit of $f(x)$ as x approaches to a	当 x 趋于 a 时 $f(x)$的极限
Δy	the increment of y	y 的增量
dy	the differential of y	y 的微分
$\mathrm{d}y/\mathrm{d}x, y'$, $D_x y$	the derivative of y with respect to x	y 对 x 的导数
$\frac{\mathrm{d}^n y}{\mathrm{d}x^n}, y^{(n)}$	the nth derivative of y with respect to x	
$\int f(x)\mathrm{d}x$	the integral of $f(x)$ with respect to x	$f(x)$ 对 x 的积分
	the primitive of $f(x)$)	$f(x)$ 的原函数
$\int_a^b f(x)\mathrm{d}x$	the definite integral of $f(x)$ from a to b	$f(x)$从 a 到 b 的定积分
I(z) ,Im(z)	the imaginary part of z	z 的虚部
R(z) ,Re(z)	real part of z	z 的实部
$\bar{z}$	the conjugate of z	z 的共轭复数
|z|	the absolute value of z	z 的绝对值
$U_n = O\ V_n$	U_n is of order V_n	和同级
	U_n/V_n is bounded	为有界
sin	sine	正弦
cos	cosine	余弦
tan	tangent	正切
cot,ctg	cotangent	余切
sec	secant	正割
csc	cosecant	余割
arcsin, $\sin^{-1}$	arc sine	反正弦
arcos, $\cos^{-1}$	arc cosine	反余弦

附录 6　课文参考翻译

第 1 课　运算放大器

一般情况下，信号放大器正如人们期望的一样工作——将信号放大。然而，信号的放大方式随着实际放大器的设计、信号的类型以及放大信号目的的不同而变化。这一点可以通过一个常见的高保真音响系统实例来加以说明。

在典型的现代高保真系统中，信号是来自于 CD 播放器、调频收音机或磁带/小型磁盘机等设备。当音乐声大小适当时，这些设备产生信号的幅度大概在 100 毫伏左右。这种信号幅度相当高，易于用示波器或电压表等仪器检测到。但是，这些信号的实际能量水平并不高。典型情况下，这些信号源只能提供毫安级的电流。根据公式 $P=VI$，其功率只有几十毫瓦。典型的扬声器需要几十瓦到数百瓦的功率才能产生足够大的声音。因此，我们需要某些形式的功率放大器(PA)来提高来自信号源的信号功率，使其足以播放音乐。

图 1.1 为四个采用不同器件的简单模拟放大器的例子。在任意一种情况下，如果实际器件的固有增益都能被所选电阻控制，电压增益就近似为 $A_v \approx -R1/R2$。注意，表达式 1-1 中的负号表明，示例中的电路在放大时改变了信号的极性。实际上，这种简单电路的增益可达 100 左右，尽管将电压增益限制在 100 以下通常更好一些。此外，真空管在英国被叫做 valves，而在美国被称为 tubes。

许多实际的放大器将多个放大器级联起来，以获得较高的电压增益。例如，一个功率放大系统的输入是来自于麦克风的 0.1 毫伏的电压，将其放大到 10 伏到 100 伏才能推动扬声器。这就要求电压的总增益达到 10^9，因此就需要很多放大器级联起来。

在很多情况下，除了信号的电压以外，我们还要放大信号的电流。这里我们考虑的例子是高保真系统中用来驱动扬声器的信号，其典型的输入电阻约为 8 欧姆。因此，要驱动 100 瓦的扬声器负载，就要同时提供 28 伏的电压和 3.5 安的电流信号。仍以麦克风作为初始信号源为例，典型的源阻抗在 100 欧左右。因此，麦克风在产生 0.1 毫伏的信号时，提供的电流仅为 1 纳安。这就表示要接受这种输入信号并去驱动 100 瓦的扬声器，放大电路就必须将信号的电流和电压同时放大 10^9 倍。这也就意味着总的功率增益为 10^{18}，即 180 分贝。

一般都将放大功能分散到单独设计的前级放大器和功率放大器中，其原因就在于功率增益很大。功率放大器中的信号幅度比微弱的输入信号大得多，即使输出的极微小的泄漏传输到输入端，都会引发一些问题。通过将大功率(大电流)和小功率放大电路分置在不同的单元中，就可以避免输入信号受到干扰。

实际上，许多需要大电流和大功率的设备往往都在特定的条件下工作，即由信号的电压决定响应的幅度，继而由设备吸收其所需要的电流而工作。例如，扬声器的音量通常是由所加电压控制。此外，大多数扬声器的效率(电能被转换为声能的效能)基本上与频率无关。在很大程度上，这是由扬声器的物理特性所产生的自然结果。这里不必考虑具体的细

节，但扬声器的输入阻抗随频率的不同而呈复杂的变化(有时也与输入信号的幅度有关)。

图 1.2 是一个典型的例子。此时，扬声器在 150 赫兹时的阻抗为 12 欧，1 千赫时的阻抗为 5 欧。所以，要达到与 150 赫兹时同样大小的输出信号，在频率为 1 千赫时就需要两倍以上的电流。功率放大器不可能预先知道将会使用的扬声器类型，因此就简单地按常规情况处理，提供一定大小的电压，表示信号中任意频率下所需信号的幅度，并提供扬声器所需要的电流。

这种特点在电子系统中很常见。用信息术语来说就是信号类型取决于电压随时间变化的情况，且在理想情况下就能吸收所需的电流。尽管上述情况是基于大功率的例子，但当传感器在输入的激励下做出响应而产生一定的电压，却只能提供有限的电流时，类似的情况也会出现。这时我们就需要一个电流放大器或缓冲器。这些装置非常相似，在各种情况下都可采用一定形式的增益装置或电路来提高信号电流的大小。不过，电流放大器总是设法对电流进行一定的放大。这与电压放大器的功能相似。缓冲器总是可以提供任何你所需要的电流，以便维持其标称电压保持不变。这就是它与电流放大器的不同之处。因此，缓冲器在连接到要求比较高的负载时就具有较高的电流增益。

第 2 课　运算放大器的基本电路

运算放大器(简称 OA)是具有高稳定性、高增益的直流差动放大器。由于运放的不同级之间没有耦合电容，因而可以对数百赫兹的直流信号进行放大。运放用于对输入的信号进行数学运算，故此而得名。

图 2.1 为运放的符号。其输入端有两个，即反相输入端(-)和同相输入端(+)。这些符号与加在输入端的信号极性无关。电源的接线在图中也给了出来。

输出信号(电压)v_o 由 $v_o = A(v_+ - v_-)$ 确定。v_+和 v_-是分别加在同相输入端和反相输入端的信号。A 表示运放的开环增益，对于理想的运放为无穷大，但对各种实际的运放，其范围通常在 10^4 到 10^6 之间。

运放需要两个工作电源，对于电路的公共端分别提供正电压和负电压。这种双极性电源使得运放可以输出任意极性的信号。输出信号的范围没有限制，实际范围取决于电源电压。因此，工作于±15V 的典型运放，其输出范围大约在-13V 到+13V，称为工作范围。任何要超出这一范围的输出都被钳位在相应的极限值上，此时运放处于饱和状态。

图 2.1 中所示的电源和电路公共端的接线此后将隐含起来。为了表达简洁，在其余的电路中就不再画出来。

由于开环增益很高，运放几乎总是与一些用来构成负反馈电路的附加电路(主要是电阻和电容)一起使用。通过这个回路，输出的一小部分被反馈到反相输入端。负反馈使输出稳定在其工作范围内，并提供一个较小但控制准确的增益，即所谓闭环增益。

运放电路在以前用于模拟计算机，并用于实时的算术运算和输入信号的调节。在市场上可以买到大量低成本的运放集成电路。

采用运放来完成各种算术运算的电路数不胜数。每一个电路由其自身的传递函数，即描述输出信号与输入信号函数关系的数学方程来描述。一般可以通过应用克希霍夫定律和以下两个简化的假设来得到传递函数：

(1) 输出信号的数值大小(通过反馈回路)实际上等于加在两个输入端上的电压，即 $v_+ \approx v_-$。

(2) 运放的两个输入端的输入阻抗很高，一般在 10^6～10^{12} MΩ的范围内，对于理想的运放则是无穷大。因此输入端没有输入电流。

反相放大器的基本电路如图 2.2 所示。考虑到电流方向的任意性，其传递函数可按以下推导而得到：

$$i_1 = (v_i - v_s)/R_i \quad 且\, i_2 = (v_s - v_o)/R_f \tag{2-1}$$

同相输入端直接连接到电路的公共端(即 $v_+ = 0$ V)，因此有

$$i_1 = v_i / R_i \quad \text{and} \quad i_2 = -v_o / R_f \tag{2-2}$$

由于输入端没有电流(简化假设 2)，即 $i_1 = i_2$，因此，反相放大器的传递函数为 $v_o = -(R_f / R_i) v_i$。

这样，反相放大器的闭环增益等于反馈电阻 R_f 与输入电阻 R_i 之比。只要所用运放的闭环增益比开环增益 A 小得多(即不能超过 1000)，这个传递函数就能准确地表示输出信号，且 v_o 的预期值在运放的工作范围之内。

加法放大器有两个或更多输入，是对上述电路的逻辑扩展，如图 2.3 所示。

加法放大器的传递函数(用类似的推导方法)为：

$$v_o = -(v_1/R_1 + v_2/R_2 + \ldots + v_n/R_n)R_f$$

这样，如果输入电阻都相等，输出就是所有输入的标量和。反之，如果输入电阻不相等，输出就是各个输入信号的加权线性和。

加法放大器用于对多个信号进行组合。两输入加法放大器最常见的应用是放大一个减去固定常数(直流偏差)的信号。

差动放大器准确地放大两个输入信号的偏差。其典型电路如图 2.4 所示。

如果 $R_i = R_i'$ 且 $R_f = R_f'$，则差动放大器的传递函数为 $v_o = (v_2 - v_1)R_f / R_i$。

差动放大器对于处理不是以电路公共地为参考端，而是以通常所说的浮动信号源等其他信号为参考端的信号非常有用。差动放大器抑制共模信号的能力使它特别适于放大受同样大小噪声(共模信号)干扰的小压差信号。

为使差动放大器能够抑制较大的共模信号并同时产生一个正好正比于两个信号偏差的输出，两个比值 $p = R_f/R_i$ 和 $q = R_f'/R_i'$ 必须完全相等。否则信号输出就是：

$$v_o = [q(p+1)/(q+1)]v_2 - pv_1$$

微分器产生一个正比于输入对时间的第一次微分的输出信号。其典型电路如图 2.5 所示。

该电路的传递函数为 $v_o = -RC(\mathrm{d}v_i/\mathrm{d}t)$。

显然，一个恒定的输入(不管幅度大小)产生的输出信号为 0。微分器在化工仪表领域中的典型应用是获取为了便于确定最后滴定点(最大斜率点)在电压滴定曲线的位置的第一个微分值。

积分器产生与输入信号对时间积分成比例的输出信号。其典型电路如图 2.6 所示。

在图 2.6 中，只要开关 S 闭合，输出就保持为 0。当开关 S 断开时，积分过程开始。输出与作为积分器件的电容 C 中所充的电荷成比例。在化工仪表中，模拟积分器的典型应用是色谱分析的峰值，因为其输出与峰值区成比例。

如果输入信号不变，积分器的输出将由如下方程确定：

$$v_o = -(v_i / RC)t$$

即输出信号将是一个斜坡电压。斜坡电压一般用于产生极谱法和许多其他伏安法技术中所需要的线性电压扫描信号。

第 3 课　CMOS 逻辑电路

CMOS 逻辑电路是一种基于互补 MOS 型晶体管来完成逻辑运算的新技术，工作时几乎不需要电流。因此，这些门在电池供电的应用中十分有用。它们可以在低到 3 伏、高到 15 伏的电压范围内工作，这也有助于实际应用。

CMOS 门都是基于如图 3.1 所示的基本非门电路。注意两只管子都是增强型的 MOSFET，一只是源极接地的 N 沟道管子，一只是源极接电源正极的 P 沟道管子。其栅极连在一起构成输入，漏极连在一起构成输出。

两只 MOSFET 具有互相匹配的特性，二者是互补的。在截止时，其电阻为无穷大，而导通时的通道电阻约为 200 欧。由于栅极实际上是开路的，因此不吸收电流。输出电压不为 0 就等于电源电压，取决于哪只管子导通。

当输入 A 接地时(逻辑 0)，N 沟道 MOSFET 没有偏置，其中就没有沟道导通。由于管子开路，因此使输出与地断开。同时，P 沟道 MOSFET 正偏，其沟道导通。该沟道的电阻约为 200 欧，将输出接到电源正极上(逻辑 1)。

当输入 A 接到电源正极时(逻辑 1)，P 沟道 MOSFET 截止而 N 沟道 MOSFET 导通，因此将输出拉低为地(逻辑 0)。这样，该电路正好实现了逻辑非的功能，同时还根据输出的状态提供有源的上拉或下拉。

通过把非门连接成部分串联、部分并联的结构，可将这种思想扩展到或非和与非结构。如图 3.2 中所示的电路为 CMOS 型两输入或非门的实例。

如果该电路中的两个输入都为低，两个 P 沟道 MOSFET 都将导通，这样就接到电源的正极上。两个 N 沟道 MOSFET 都将截止，因此就不会与地接通。然而，如果任一个输入变高，P 沟道 MOSFET 就截止，并断开与电源正极的连接，而 N 沟道 MOSFET 将导通，将输出接地。

该电路可以颠倒结构顺序，如图 3.3 所示。这是一个两输入的与非门，任一输入的逻辑 0 都会使输出为逻辑 1，但只有两个输入都为逻辑 1 时才会使输出变为逻辑 0。

这种结构比同等功能的双极性电路更灵活一些，但还存在一些实际的限制。限制之一就是串联连接的 MOSFET 的复合电阻。因此，CMOS 图腾柱的高电平输入最多不会超过 4 个。输入多于 4 个的门设计成级联的形式，而不会采用单一的结构。当然，其逻辑功能仍然是有效的。

即使在这种限制下，图腾柱结构在某些特定的应用中还会带来一些问题。输出的上拉电阻和下拉电阻永远不一样，并且即使输出的逻辑状态不变，在输入改变状态时电阻会变化很大。其结果是输出出现不确定的上下反复变化。这个问题通过缓冲器或 B 系列的 CMOS 门处理可以得到解决。

如图 3.4 所示，处理方法是在实际的与非门后加一对反相器。这样，输出就总是由 N 沟道或 P 沟道管子中的一只管子来驱动。由于它们尽可能互相匹配，门电路的输出电阻就

总是一样的，信号的特性也因此更加确定。

CMOS 门的一个主要问题是工作速度。由于固有的输入电容的影响，它们不可能工作得很快。通过提供同样的输出电流并快速切换输出状态，即使输入信号变化缓慢，B 系列器件也在一定程度上克服了这些局限性。

应该说明的是，这里并没有探讨 CMOS 门电路的技术细节。例如，为了避免静电的损坏，各个制造商都开发了各种输入保护电路来防止输入电压变得过高。不过，这些保护电路并不影响门电路的逻辑特性，这里我们就不详细讨论了。

第 4 课　触　发　器

锁存器和触发器是开关电路中常用的两种存储器件。锁存器是由输入信号控制器件输出状态的存储元件。如果一个锁存器是由输入信号使其输出为 1，则该锁存器被称为置位锁存器。若是由输入信号使其输出为 0，则称为复位锁存器。如果一个锁存器既有置位又有复位激励信号，就称为置—复位锁存器。触发器与锁存器的不同之处是它有时钟控制信号。时钟信号发出命令，使器件的状态根据激励输入信号而改变。大多数基本触发器被称为锁存器。

基本 RS 触发器 基本 RS 触发器通常被称为 RS 锁存器，是由两个十字交叉的或非门或者与非门组成的电路。它有两个输入端—S 为置位端，R 为复位端。图 4.1 所示为两个十字相交的或非门。

当输入端 S=1 且 R=0 时，输出端 Q=1，$\overline{Q}$ =0，被称为置位状态；当输入 R=1，S=0 时，输出 Q=0，$\overline{Q}$ =1，称为复位状态。输入都为 0 时，触发器或者为置位状态，或者为复位状态，这主要取决于哪个输入端被最后置为 1。两个输入都为 1 时，输出的状态不定，这是因为当两个输入都变为 0 时，造成次态的不确定。输出 Q 和 $\overline{Q}$ 通常是相反的。真值表如表 4−1 所示。

由两个交叉的与非门构成的 RS 触发器如图 4.2 所示。触发器的两个输入通常都为 1，除非其状态需要改变。S=0 会使 Q=1，触发器处于置位状态。当 S 回到 1 时，电路仍处于置位状态。只有当两个输入都为 1 后，才能通过使 R=0 来改变触发器的状态，使电路为复位状态并一直保持，甚至在两个输入都变为 1 时仍保持为复位状态。当两个输入同时为 0 时，与非门触发器处于不定态。功能表见表 4-2。

同步 RS 触发器 通过给基本 RS 触发器提供一附加控制信号可以改变其工作方式，这一控制信号决定触发器的状态何时可以改变。这种触发器被称为同步 RS 触发器，如图 4.3 所示。它由基本 RS 触发器和两个附加与非门构成。控制输入端 CP 作为其他两个输入端的使能信号，只要控制输入保持为 0，与非门的输出即为 1，这就是基本 RS 触发器的静态条件。当控制输入变为 1 时，S 和 R 的状态才会影响基本 RS 触发器的输出。CP=1、R=1 且 S=0 为复位状态，CP=1、R=0 且 S=1 为置位状态。当 CP 恢复到 0 时，控制输入失效。因此，无论 R 和 S 为何值，输出状态都不变。而且当 CP=1、S 和 R 都为 0 时，输出状态也不变。状态表如表 4−3 所示。

当三个输入都为 1 时属于不确定状态，这就使该电路不便于应用，因此在实践中很少使用。然而它仍是一种重要电路，因为它能构成其他的锁存器和触发器。

主从 RS 触发器 防止上述不稳定特性的一个方法是采用主从结构的两个锁存器，如图 4.4 所示。两个锁存器的控制信号相反。当时钟信号 CP 为高时，主触发器处于选通状态，从触发器处于保持状态。当时钟信号变为 0 时，两个触发器的状态互换。从触发器进入选通状态，将主触发器的输出传送到主从触发器的输出端 Q。当主触发器进入保持状态，不再受输入信号变化的影响。主从 RS 触发器的功能表如表 4-4 所示。

主从 JK 触发器 当 $S=R=1$ 时，我们希望主从 RS 触发器的状态是确定的，因此我们对主从 RS 触发器的结构进行了改进。输出 Q 和 $\overline{Q}$ 连接到输入端作为一对附加控制信号。由 J、K 代替原电路中的 R、S，该触发器就称为 JK 触发器。JK 触发器可以认为是主从 RS 触发器的扩展。

主从 JK 触发器的特点是当 $J=K=1$ 时状态翻转，即从 0 变 1 或从 1 变到 0。4 种工作方式(保持、置位、复位和翻转)概括在表 4−5 中的功能表中。

第 5 课　控制系统简介

自动控制在工程和科学领域起着很重要的作用。除了在宇宙飞船、导弹的制导和飞机驾驶系统中起重要作用外，自动控制已经成为现代生产及工业过程中重要而不可缺少的组成部分。例如，在工业生产中诸如压力、温度、湿度、黏度和加工业的流量控制中，以及制造业中零部件的加工、处理、装配及其他许多行业中，自动控制都是不可或缺的。

由于自动控制理论和实践的不断发展给人们提供了获得动态系统最佳特性的方法，提高了产品质量，降低了生产成本，提高了生产率，使人们从繁重的日常工作和重复的手工操作中解放出来。因此，大多数工程师和科学工作者现在都必须具备这一领域的知识。

自动控制方面的第一项伟大成果是 18 世纪詹姆斯 •瓦特用于蒸汽机速度控制的离心调速器。对于早期控制理论发展起重要作用的人还有迈那斯基、黑曾和奈奎斯特等人。1922 年，迈那斯基研究用于驾驶船舶的自动控制器，并指出系统的稳定性由描述系统的微分方程决定。1934 年，曾提出了用于位置控制系统的伺服机构这一概念的黑曾论述了可以精确跟踪输入信号变化的继电式伺服机构的设计。

在 20 世纪 40 年代的十年间，借助于频域响应法，工程师们得以设计出满足性能要求的线性反馈控制系统。40 年代末 50 年代初，根轨迹法在控制系统设计中得到了全面发展。

使用作为古典理论核心的频域法和根轨迹法设计出的系统是稳定的并且或多或少地满足任意一组性能要求。一般来说，这样的系统并不是特定意义上的最优系统。50 年代后期以来，控制系统设计问题的重点已不再是设计许多可行系统中的一种系统，而是设计在某种意义上的一种最优系统。

因为多输入多输出的现代对象越来越复杂，所以就要用大量方程来描述一个现代控制系统，而只能处理单输入单输出系统的古典控制论对多输入多输出系统无能为力。大概从 1960 年起，现代控制理论已被用于处理日益复杂的现代对象，以及对精度、重量严格要求的工业应用。

在复杂的运算中，由于模拟、数字和混合电子计算机的使用随处可见，因此在控制系统设计中使用计算机和控制系统运行中使用在线计算机正变得日益普遍。

现代控制论的最新成果是确定性和随动系统的最优控制及复杂系统的自适应和学习控

制。现在，现代控制论被用在如生物学、经济学和社会学等非工程领域，在不久的将来在这些领域应用中定会有佳音传来。

接下来我们介绍一下描述控制系统的必要术语。

对象 对象是一台设备或者为完成某一操作而组合在一起的一组机器零件。这里我们称任何被控制对象(如加热炉、化学反应器或一架飞机)为被控对象。

过程 麦里亚－韦伯斯特字典将过程定义为一种自然的、持续性的操作或演变进程，其特征是一系列渐进的变化以相对固定的方式相继发生在操作或演变进程中，并产生特定的效果或结果；或者是人为或自发的、持续性的、由一系列产生特定结果的被控操作或动作组成的工序。这里我们把任何被控制的操作都称为过程，诸如化学过程、经济过程和生物过程。

系统 系统是为了完成特定任务而共同作用的部件的组合。它并不限于诸如经济学中遇到的抽象的动态现象。因此，“系统”这个词的理解应包含物理、生物和经济等系统。

扰动 扰动是对系统输出产生不利影响的信号。产生在系统内的扰动称为内部扰动，产生于系统外则称为外部扰动，并且是系统的输入信号。

反馈控制 反馈控制是当扰动出现时减小系统输出量与参考输入量(或任意变化的期望状态)之间偏差的操作，并且其工作原理是基于该偏差。这里的扰动仅指不可预测的，因为可预测或已知扰动总可以在系统中进行补偿，因此就不必要测量。

反馈控制系统 反馈控制系统的目的是通过比较来保持输出与参考输入之间的偏差为既定关系，并且利用这一偏差作为控制的手段。

值得注意的是，反馈控制系统并不局限在工程领域，诸如经济和生物等非工程领域也存在。例如，在一定意义上，人体就是一个类似具有多个单元操作的复杂的化学对象。这一传输和化学反应网络的过程控制包含很多控制回路。事实上，人本身就是一个相当复杂的反馈控制系统。

伺服系统 伺服系统是输出为某一机械位移、速度或加速度的反馈控制系统。因此，伺服系统和位置(速度、加速度)控制系统是同义的。伺服系统在现代工业中应用得十分广泛。例如，采用程序控制的机床的全自动化操作就可以由伺服系统来完成。

自动调节系统 自动调节系统是保持参考输入或期望的输出为常量或随时间缓慢变化的反馈系统，其主要任务是在出现扰动时，使实际输出保持为期望值。

用恒温器作为控制器的室内供暖系统就是一种自动调节系统。系统中恒温器的温度给定值(即温度的期望值)与室内实际温度相比较。系统中温度期望值的变化就是干扰。其目标是在室外温度变化时保持室内温度为期望值。自动调节系统的例子还有很多，如压力的自动控制及电压、电流或频率等电学量的自动控制。

过程控制系统 输出为温度、压力、流量、液位或者 pH 值等变量的自动调节系统称为过程控制系统。过程控制在工业中应用广泛。在加热炉的温度控制中，炉温是按给定程序控制的，称为程序控制。过程控制系统中经常采用程序控制。例如，一个预置的程序可以是这样的，炉温在给定时间内上升到给定值，然后在预定时间内又下降到另一给定值。在该程序控制下，设定值随着预置的时间表变化。控制器的作用是保持炉温随着变化的设定值而改变。应指出的是，大多数过程控制系统都将伺服系统作为系统的必要组成部分。

第 6 课　物理系统的数学模型介绍

许多动态系统，不管是机械的、电气的、热力的、液压的、经济的还是生物的系统，其特性都可用不同的微分方程来描述。解出这些微分方程，就可以得到动态系统在特定输入(或作用函数)下的响应。可以利用支配特定系统的物理定律来得到方程，如力学系统的牛顿定律和电气系统的克希霍夫定律等。

数学模型 系统动态特性的数学描述叫数学模型。动态系统分析的第一步就是推导出其模型。我们必须记住，推导出合适的数学模型是整个分析中最重要的一部分工作。

模型可以采用多种形式。对于特定的系统和应用环境，数学描述可能比其他描述更合适一些。例如，在最优控制问题中，用一组一阶微分方程通常要方便一些。另一方面，对于单输入-单输出系统的暂态响应分析或频率响应分析，采用传递函数表示比用其他方法就更方便一些。

一旦得到了系统的数学模型，就可以利用各种分析方法和计算机工具进行分析和综合。

简单与精确 在推导模型时，我们必须在简单模型和分析结果的精确之间折衷考虑。应当注意的是，分析结果的准确程度仅取决于数学模型对给定物理系统的近似程度。

用计算机进行数学运算速度很快，这样我们就可以采用新的方法来建立数学模型。如有必要，我们可以用上百个方程来描述一个完整的系统，而不局限于使用简单的模型。当然，如果不需要很高的精度，仅用合理简化的模型则更好一些。

在推导这样的简化模型时，我们经常会发现需要忽略系统某些固有的物理属性。特别是在需要采用线性集中参数数学模型(即常微分方程)时，总是要忽略掉物理系统中存在的一定的非线性因素和分布参数(即产生偏微分方程的参数)。如果这些忽略掉的特性对于响应的影响较小，则数学模型分析结果和物理系统试验研究结果就能很好地吻合。

在求解新问题时，我们通常会发现，先建立简化的模型，就可以得到解决方案的一般性的认识，这样更好一些。然后再建立较完善的数学模型，以便进行更全面的分析。

在低频工作时有效的线性集中参数模型，在频率高到一定程度时不一定有效，因为忽略掉的分布参数特性可能成为系统动态特性中的重要因素。我们对此必须十分明确。例如，弹簧的质量在低频工作时可以忽略，但在高频时却变成系统的重要性质。

线性系统 线性系统是指模型的方程是线性的系统。如果方程的系数为常数或者仅是自变量的函数，则属于线性微分方程。线性系统的最重要的特性是适用于叠加原理。叠加原理表明，两个不同的作用函数同时作用于系统时的响应等于两个作用函数单独作用时的响应之和。因此，线性系统在多输入下的响应，可以分别单个处理，然后将各个响应相加而得到。基于这一原理，可以从简单解求出线性微分方程的复杂解。

在动态系统的试验研究中，如果输入和输出成比例，就意味着满足叠加原理，该系统就可以认为是线性的。

线性定常系统与线性时变系统 由定常集中参数元件组成的线性动态系统可以用线性定常微分方程来描述。这样的系统就称为线性定常(或线性常系数)系统。如果描述系统的微分方程的系数是时间的函数，该系统就称为线性时变系统。航天器控制系统就是一个时变控制系统的例子。(航天器的质量由于燃料消耗而变化，航天器在离开地球时，重力也发

生变化。)

非线性系统 非线性系统是指用非线性方程描述的系统。非线性方程的例子如：

$$y = \sin\ x \tag{6-1}$$

$$y = x^2 \tag{6-2}$$

$$z = x^2 + y^3 \tag{6-3}$$

(最后一个方程中的 z 是 x 和 y 的非线性函数。)

不是线性的微分方程就叫做非线性微分方程。非线性微分方程的例子如：

$$\frac{\mathrm{d}^2x}{\mathrm{d}t^2} + \left(\frac{\mathrm{d}x}{\mathrm{d}t}\right)^2 + x = A\sin\omega t \tag{6-4}$$

$$\frac{\mathrm{d}^2x}{\mathrm{d}t^2} + \left(x^2 - 1\right)\frac{\mathrm{d}x}{\mathrm{d}t} + x = 0 \tag{6-5}$$

$$\frac{\mathrm{d}^2x}{\mathrm{d}t^2} + \frac{\mathrm{d}x}{\mathrm{d}t} + x + x^2 = 0 \tag{6-6}$$

虽然很多物理关系通常用线性方程表示，但多数的实际关系并非真正的线性。事实上，对物理系统的仔细研究表明，即使所谓的“线性系统”也只是在有限的工作范围内是真正的线性。实际上，许多机电系统、液压系统和气动系统等的变量之间都存在非线性关系。例如，在较大的输入信号作用下，元件的输出可能饱和。可能存在影响小信号的死区。(元件的死区是输入变化的一个小范围，在这个范围内元件不敏感。)平方率非线性可能存在于某些元件中。例如，物理系统中使用的阻尼器在低速工作时可能是线性的，但在高速时可能变成非线性，而且阻尼力可能变得与工作速度的平方成正比。

应当指出，某些重要的控制系统对于任意大小的信号都是非线性的。例如，在继电器控制系统中，控制作用不是开就是关，控制器的输入与输出之间就不存在线性关系。

非线性系统最重要的性质就是叠加原理不再适用。对包含非线性系统的问题进行求解，其过程一般都很复杂。由于非线性系统在数学上(求解)的困难，常需引入“等效”的线性系统来代替非线性系统。一旦非线性系统用线性的数学模型来近似表示，很多线性工具就可以用来进行分析和设计。在实际应用中，线性化的方法有很多。

第 7 课　基本控制作用与工业控制器

自动控制器把对象的实际输出与期望值进行比较，确定偏差，并产生一个使误差为零或微小值的控制信号。自动控制器产生控制信号的方式叫做控制作用。

我们这里将介绍工业自动控制器中常用的基本控制作用。首先，我们要介绍自动控制器的工作原理以及利用误差信号的微分和积分来产生各种控制信号的方法。然后，我们将讨论某些特定的控制方式对系统性能的影响。接着，我们简要讨论一下降低外部干扰影响系统性能的方法。最后，我们将介绍流体放大器、射流的基本原理及射流器件的应用。

工业自动控制器的分类 根据控制作用，工业自动控制器可分为：

(1) 双位或继电器控制器；

(2) 比例控制器；

(3) 积分控制器；

(4) 比例-积分控制器；

(5) 比例-微分控制器；

(6) 比例-微分-积分控制器。

多数工业自动控制器采用电或诸如油或空气一类的压缩流体作为能源。自动控制器还可以根据工作时使用的能源来分类，如气动控制器、液压控制器或电动控制器。控制器的选用取决于对象的性质和工作条件，包括安全性、实用性、可靠性、精度、重量和体积等方面的考虑。

工业自动控制器的元件 自动控制器必须检测出功率通常很小的误差信号，并将其放大到足够大的强度。因此，放大器是必不可少的。自动控制器的输出被传送到动力设备，如气动发动机或气动阀、液压电机或电动机。

控制器一般由误差检测器和放大器组成。测量元件是将输出量转换为其他适当形式的器件，以便于将输出量与位移、压力或电信号等参考输入信号进行比较。该元件一般在闭环系统的反馈回路中。控制器的设定值必须转换为与测量元件的反馈信号单位相同的参考输入信号。放大器将误差信号进行放大，用以控制执行机构。执行机构是根据控制信号的大小改变对象输入的设备。这样就可以使反馈信号与参考输入信号一致。

自操作控制器 在多数工业自动控制器中，测量元件和执行机构都是独立的装置。只是在像自操作控制器这样简单的控制器中，才将它们组合为一个整体。自操作控制器利用测量元件产生能源，结构简单，价格低廉。给定值通过调节弹簧的弹力来确定，被控压力由膜片测量。误差信号是作用在膜片上的净力，膜片的位置决定了阀的开度。

自操作控制器的工作原理为：假定输出压力低于由给定值确定的参考压力，向下的弹力就大于向上的弹力，膜片就向下运动，流速因此加快，压力随之上升。当向上的压力等于向下的弹力时，阀塞趋于平衡，流速就稳定下来。相反，如果输出压力高于参考压力，阀门的开度变小，流速下降。这样的自操作控制器广泛应用于水和气体的压力控制。在这类控制器中，通过阀门的流速近似与误差信号成比例。

控制作用 在工业自动控制器中常见的基本控制作用有如下 6 种：双位或继电器型、比例、积分、比例-积分、比例-微分和比例-微分-积分控制作用。应当说明的是，为了方便控制，工程师选择一种最适于特定用途的控制作用，因此了解各种控制作用的基本特性是十分必要的。

双位或继电器控制作用 在双位控制系统中，执行机构多数情况下只有开和关两个固定位置。双位或继电器控制相对简单且便宜，因而在工业和家用控制系统中都应用得十分广泛。

假定控制器的输出信号为 $m(t)$，误差信号为 $e(t)$。在双位控制中，当误差信号为正或负时，$m(t)$ 则对应保持为最大值或最小值。因此，

$$
\begin{aligned}
m(t) &= M_1 \text{ for } e(t) > 0 \\
&= M_2 \text{ for } e(t) < 0
\end{aligned}
$$

式中的 M_1 和 M_2 为常数。最小值 M_2 不是 0 就是 $-M_1$。双位控制器通常是电动设备，而电磁线圈控制阀在这类控制器中应用广泛。高增益的气动比例控制器起着双位控制器的作用，有时也叫做气动双位控制器。

考察具有双位控制的液位控制系统，阀门非开即关。因此，水的流入速度不是正值就

是 0。输出信号在两个要求的极限位置之间连续变化，使执行元件从一个固定位置运动到另一个固定位置。注意，输出曲线按照两条指数曲线中的一条变化。一条是灌水曲线，一条是排水曲线。这种在两极之间的输出振荡是系统在双位控制下的典型响应特性。

我们可能注意到，减小差动间隙可以降低输出振荡的幅度。当然，这样就增加了开关每分钟动作的次数，同时也缩短了器件的使用寿命。差动间隙的大小必须根据要求的精度和元件的寿命等因素来确定。

比例控制作用 对于具有比例控制作用的控制器，其输出值 $m(t)$ 与误差信号 $e(t)$之间的关系为：

$$m(t) = k_p e(t) \tag{7-1}$$

或采用拉普拉斯变换的参量形式：

$$\frac{M(s)}{E(s)} = k_p \tag{7-2}$$

式中的 k_p 称为比例灵敏度或增益。

不管实际上采用何种机构，也不管其工作能源的形式，比例控制器实际上就是一个增益可调的放大器。

积分控制器 在具有积分控制作用的控制器中，其输出值 $m(t)$ 与误差信号 $e(t)$变化的速率成正比。即：

$$\frac{\mathrm{d}m(t)}{\mathrm{d}t} = k_t e(t) \tag{7-3}$$

或

$$m(t) = k_t \int_0^t e(t)\mathrm{d}t \tag{7-4}$$

式中的 k_p 为可调常数。积分控制器的传递函数为：

$$\frac{M(s)}{E(s)} = \frac{k_t}{s} \tag{7-5}$$

如果 $e(t)$ 的值加倍，$m(t)$ 的变化速度也加倍。如果误差信号为 0，$m(t)$ 就保持不变。积分控制作用有时也称为复位控制。

比例-积分控制作用 比例-积分控制器的控制作用由下面的方程定义：

$$m(t) = k_p e(t) + \frac{k_p}{T_t}\int_0^t e(t)\mathrm{d}t \tag{7-6}$$

控制器的传递函数为：

$$\frac{M(s)}{E(s)} = k_p\left(1 + \frac{1}{T_t s}\right) \tag{7-7}$$

其中，k_p 表示比例灵敏度或增益，T_t 表示积分时间，二者都是可调的。积分时间只调节积分控制作用，k_p 的变化则同时影响控制作用的比例部分和积分部分。积分时间 T_t 的倒数叫做复位速率，它表示控制作用中比例部分每分钟增加的倍数，并且用每分钟加倍的次数来衡量。

比例-微分控制作用 比例-微分控制器的控制作用由下面的方程定义：

$$m(t)=k_pe(t)+k_pT_d\frac{\mathrm{d}e(t)}{\mathrm{d}t} \tag{7-8}$$

其中，k_p 表示比例灵敏度，T_d 表示微分时间，二者都是可调的。微分控制作用有时也叫做速率控制，是控制器输出值中和误差信号变化的速率成比例的部分。微分时间 T_d 是速率控制作用超前于比例控制作用的时间间隔。微分控制作用具有超前的特性。当然，它实际上不可能预知还没有发生的情况。

由于微分作用具有超前的优点，也就伴随了连带噪声信号一起放大的缺点，因而可能造成执行机构的饱和。

注意：由于微分控制作用仅仅在过渡过程中起作用，因而不能单独使用。

比例-微分-积分控制作用 比例、微分和积分控制作用的组合称为比例-微分-积分控制作用。这种组合作用具有 3 种控制作用各自的优点。具有组合作用的控制器的方程为：

$$m(t)=k_pe(t)+k_pT_d\frac{\mathrm{d}e(t)}{\mathrm{d}t}+\frac{k_p}{T_t}\int_0^t e(t)\mathrm{d}t \tag{7-9}$$

传递函数为：

$$\frac{M(s)}{E(s)}=k_p(1+T_ds+\frac{1}{T_ts}) \tag{7-10}$$

其中，k_p 表示比例灵敏度，T_d 表示微分时间，T_t 表示积分时间。

测量元件对系统性能的影响 由于测量元件的动态和静态特性影响输出变量的实际测量值，因而在决定控制系统的整体性能时，测量元件具有很重要的作用。测量元件通常决定反馈回路中的传递函数。如果测量元件的时间常数与控制系统中的其他时间常数相比小得可以忽略，其传递函数就简化为一个常数。热能测量元件的响应一般属于二阶过阻尼的类型。

自动控制系统的方块图 简单的自动控制系统的方块图可以通过把对象与控制器连接起来而得到，如图 7.1 所示。输出信号通过测量元件实现反馈。输出变量 $C(s)$ 对于参考输入 $R(s)$ 和扰动变量 $N(s)$ 的关系可由下式表示：

$$C(s)=\frac{G_1(s)G_2(s)}{1+G_1(s)G_2(s)H(s)}R(s)+\frac{G_3(s)}{1+G_1(s)G_2(s)H(s)}N(s) \tag{7-11}$$

在过程控制系统中，我们总是对负荷扰动 $N(s)$的响应感兴趣。但在随动系统中，我们最感兴趣的则是对于变化着的输入 $R(s)$的响应。

我们将在后面说明比例控制器中应用负反馈的原理，并通过气动控制器的分析来详细探讨比例控制器的工作原理，然后说明同样适用于液压和电动控制器的原理。在整个讨论过程中，我们注重的是基本原理，而不是实际机构的工作细节。

第 8 课　系统设计和补偿技术

控制系统被设计用来执行特定的任务。对控制系统的要求通常被称为系统的性能指标。它们通常和系统精确度、相对稳定性以及响应速度有关。

一般地，系统的性能指标不应该比该系统执行给定任务时所必须达到的指标更加苛刻。

对于某一个给定的系统而言，如果稳态运行精度是最为重要的，那么，我们就不应该提出不必要的过高的暂态性能指标要求。满足这些过高的暂态性能指标往往需要昂贵的部件。我们应该牢记，控制系统设计过程中最重要的一个环节就是把性能要求精确地表达出来，这样才会设计出对于给定的任务而言最优的控制系统。

在本课中，我们将简要地介绍使用频率响应法和根轨迹法对单输入单输出线性定常系统进行设计和补偿的方法。补偿是指改变系统的动态特性以满足给定的指标。

调节一个系统以得到满意性能的第一步是设定它的增益。在很多情况下，增加增益值将改善系统的稳态性能，但是也将使系统稳定性变差，甚至变得不稳定。于是必须重新设计系统(修改结构或者增加装置或部件)，改变总体特性，使系统按照我们所希望的那样运行。

图 8.1 所示的结构中，补偿器 $G_C(s)$ 和被控对象串联连接。这种方法称为串联补偿。另外一种补偿是反馈补偿。串联补偿通常比反馈补偿简单。

在讨论补偿器时，我们经常使用的术语是超前网络、滞后网络以及滞后-超前网络。如果一个正弦信号 e_i 加到一个网络上，它的稳态输出 eo (也是正弦信号) 相位超前，则该网络称为超前网络。类似地，如果稳态输出 eo 相位滞后，则该网络称为滞后网络。在滞后-超前网络中，相位滞后和相位超前两种情况都会出现，但是出现在不同的频率范围内；相位滞后出现在低频段，相位超前出现在高频段。

控制系统设计的根轨迹法

根轨迹法是一种图解的方法。已知开环零点和极点的位置，当某个参数(通常是增益)的值从零变化到无穷大时，可以确定所有可能的闭环极点的位置。本方法清楚地显示出参数调节的效果。实际上，系统的根轨迹图表明，仅仅通过调节增益并不能获得理想的性能。于是，必须改变根轨迹的形状来满足性能指标。

在设计控制系统时，我们可以通过插入一个合适的补偿器 $G_C(s)$ 来改变原来的根轨迹(如图 8.1 所示)。一旦完全理解了增加极点和/或零点对于根轨迹的影响，我们就可以很方便地确定补偿器零点极点的位置，以使根轨迹变成我们所希望的形状。在用根轨迹法设计的过程中，通过使用补偿器改变系统根轨迹的形状，以使闭环系统一对主导极点位于理想的位置。(通常，阻尼比和无阻尼自然振荡频率是由闭环系统一对主导极点的位置确定的。)

在开环传递函数中增加一个极点的效果是把根轨迹向右推，倾向于降低系统的相对稳定性，并且降低系统的收敛速度。增加一个零点的效果是把根轨迹向左推，倾向于使系统更加稳定，并且加快系统的响应。

当系统的性能指标以时域的量(如阻尼比及无阻尼自然频率、最大超调量、上升时间和调节时间)给出时，采用根轨迹法设计是非常有效的。

让我们考虑一个设计问题。原系统要么对所有的增益值均不稳定，要么虽然稳定但是动态响应特性不理想。在这种情况下必须改变根轨迹的形状，以使闭环主导极点位于复平面中的理想位置上。在前向传递函数中串联插入一个适当的超前补偿器，就可以解决这个问题。

频率响应法控制系统设计

需要注意，在控制系统的设计中，暂态响应性能通常是最重要的。在频率响应法中，

我们用相角裕量及增益裕量、谐振峰值幅度、增益穿越频率、谐振频率和带宽来表征暂态响应。尽管暂态响应和频率响应的相互关系是间接的，但是频域的指标可以由伯德图很方便地达到。

频域中的设计简单而直观。当开环系统由频率法设计完成以后，闭环的零点和极点就可以确定了。必须检查暂态响应特性，以确认设计的系统是否满足时域的要求。如果不满足要求，必须修改补偿器，重新分析，直到获得满意的结果。

频域中的设计主要有两种方法。一种是极坐标图法，另一种是伯德图法。用伯德图更方便一些。补偿器的伯德图可以简单地加在原伯德图上，因此画完整的伯德图是很简单的事。而且，如果改变开环增益，幅值曲线上下移动，曲线的斜率不变，并且相位曲线也保持不变。

用伯德图设计的常用方法是，我们首先调节开环增益，以使稳态精度的要求得到满足。然后，我们画出尚没有校正的开环幅值曲线和相位曲线。如果对于相位裕度和幅值裕度的指标没有满足，就确定一个改造开环传递函数的合适的补偿器。

在多数情况下，补偿实际上是在稳态精度和相对稳定性之间作一个折衷。为了获得较大的速度误差常数以及满意的相对稳定性，我们发现需要重新构造开环频率响应曲线。低频段的增益应该大到满足稳态精度要求。在中频段(从两个方向靠近幅频曲线的穿越频率 ω_C)，伯德图中对数幅频曲线的斜率应该为－20dB/dec。这一斜率应该具有足够宽的频率范围，以确保得到适当的相角裕度。对于高频段，幅值曲线应该尽可能快地衰减，以减小噪声的影响。

超前补偿、滞后补偿和滞后-超前补偿的基本特性如后面所述。超前补偿对于暂态响应有明显的改进，对稳态精度改进较小。它可能加强高频噪声的影响。另一方面，滞后补偿明显提高了稳态精度，代价是增加了暂态响应时间。滞后补偿会抑制高频噪声信号的影响。滞后-超前补偿综合了超前补偿和滞后补偿两者的特点。

第 9 课　非线性控制系统

在实际控制系统中存在多种不同类型的非线性。根据它们是系统本身内在的，还是人为故意加入系统中的，可以将非线性分为两类。

下面我们将首先讨论固有的非线性，然后再讨论人为的非线性。然后我们讨论非线性控制系统的分析和设计方法。

描述系统的微分方程如下所示：

$$k_n x^{(n)} + \cdots + k_2 \ddot{x} + k_1 \dot{x} + k_0 x = u(t) \tag{9-1}$$

如果所有的系数 $k_n,\cdots,k_0$ 都是常数，则该系统是线性定常系统。如果 $k_n,\cdots,k_0$ 中有一个或者一个以上是变量 x 或其导数的函数，则该系统为非线性系统。如果 $k_n,\cdots,k_0$ 中有一个或者一个以上是自变量 t 的函数，则系统是时变系统。

叠加原理不适用于非线性系统。因此，到目前为止我们所讨论的线性定常系统的分析和设计方法，包括传递函数和拉普拉斯变换的应用，都不再有效。更糟糕的是，没有通用的等价方法来代替它们。当然，非线性系统的分析方法也很多，但是用途都很有限。本课

中，我们将简要地介绍相平面法和描述函数法。

充分了解线性定常系统和非线性系统之间的区别非常重要。非线性系统通常具有下列特点：

1. 响应特性既依赖于输入又依赖于初始条件。例如，如果阶跃输入的幅度增加一倍，非线性系统就有可能从稳定变为不稳定。

2. 系统的不稳定性往往以极限环的形式呈现。极限环是指即使系统的输入为零，在反馈回路中持续存在固定频率和振幅的振荡。

3. 在正弦输入信号的稳态响应中可以包含该输入信号频率的谐波成分以及次谐波成分。

常见的非线性类型如图 9.1 所示。x 为输入，y 为输出。它们是控制系统中某些元件的固有属性。

有些非线性元件是人为加到系统中的，用以改善系统性能或简化系统结构，或二者兼具。这种人为的非线性系统的最简单例子是常规的继电器控制系统。我们也可以在采用复杂的非线性控制器的最优控制系统中找到其他例子。应当指出，在某些特定的工作条件下，尽管人为的非线性元件可以改善系统的性能，但在其他工作条件下通常会降低系统性能。

相平面法

相平面法是确定一阶和二阶系统暂态响应的图解法。考虑下列非线性方程：

$$\ddot{x}+g(x,\dot{x})\dot{x}+h(x,\dot{x})x=0 \tag{9-2}$$

设 $y=\dot{x}$，于是有 $\ddot{x}=\dot{y}=\dfrac{\mathrm{d}y}{\mathrm{d}x}\cdot\dfrac{\mathrm{d}x}{\mathrm{d}t}=\dfrac{\mathrm{d}y}{\mathrm{d}x}\cdot\dot{x}=y\cdot\dfrac{\mathrm{d}y}{\mathrm{d}x}$。把它们代入(9-2)式，得：

$$y\cdot\frac{\mathrm{d}y}{\mathrm{d}x}+g(x,y)y+h(x,y)x=0 \tag{9-3}$$

将(9-3)式整理后得相平面方程。

$$\frac{\mathrm{d}y}{\mathrm{d}x}=\frac{-g(x,y)y-h(x,y)x}{y} \tag{9-4}$$

相平面图是 y 关于 x 变化的曲线图。在每一点(x , y)上，$\mathrm{d}y/\mathrm{d}x$ 是通过该点轨迹的斜率。等倾线是具有相同曲线斜率的轨迹线。$\mathrm{d}y/\mathrm{d}x=m$ 时的等倾线方程是：

$$y=\frac{-h(x,y)x}{g(x,y)+m} \tag{9-5}$$

这种图形方法称为等倾线法，对绘制相平面曲线有用。

描述函数法

描述函数法是一种分析响应的方法，主要用于稳定性分析(即预测是否存在极限环)。在图 9.2 中，G_1 和 G_2 表示系统的线性部分，N 表示非线性元件。

在图 9.2 中，对模型 N 的分析是基于这样的假设：该非线性元件的输入 x 为正弦信号。

$$x=A\sin\omega t \tag{9-6}$$

非线性元件的输出是和输入信号频率相同的周期信号。忽略 y 的谐波成分，我们可以定义描述函数为：

$$N(A)=\left|N(A)\right|\mathrm{e}^{j\angle N(A)}=\frac{Y_1}{A}\mathrm{e}^{j\phi_1} \tag{9-7}$$

系统的特征方程为：

$$G_1(s)G_2(s)=-1/N(A) \tag{9-8}$$

对于具有一个非线性元件的控制系统，奈奎斯特稳定性判据将相应地改变。描述函数法可以为任意阶次的系统提供稳定性信息，但是，它不能提供时间响应特性的准确信息。

第 10 课　相平面法简介

考虑一个由下面常微分方程所描述的二阶系统：

$$\ddot{x}+f(x,\dot{x})=0 \tag{10-1}$$

式中 $f(x,\dot{x})$ 是 x 和 $\dot{x}$ 的线性函数或者非线性函数。该系统的时间解可以由 $x(t)$ 的曲线形式得到，也可以通过以 t 作为参数画出 $\dot{x}(t)-x(t)$ 曲线图来说明。

我们将 x 和 $\dot{x}$ 作为平面的坐标轴，并且平面上的每个点都表示 x 和 $\dot{x}$ 的值。随着 t 变化，这一点沿着 x-$\dot{x}$ 平面中的一条曲线移动，表示系统状态的轨迹。这样的曲线称为轨迹。

系统特性以轨迹形式的几何表示方法称为系统动态特性的相平面表示。尽管相平面图可以清楚地给出二阶系统的轨迹图，但是对于 3 阶系统通常难以描绘和构造轨迹。对于高于 3 阶的系统，不可能画出轨迹。然而，在二维空间中表示状态点移动的思想在概念上可以扩展到 n 维空间。

我们将通过下面的例子解释相平面法。系统的微分方程组是：

$$\frac{\mathrm{d}x_1}{\mathrm{d}t}=f_1(x_1,x_2) \tag{10-2}$$

$$\frac{\mathrm{d}x_2}{\mathrm{d}t}=f_2(x_1,x_2) \tag{10-3}$$

式中 $f_1(x_1,x_2)$ 和 $f_2(x_1,x_2)$ 分别是 x_1 和 x_2 的线性或者非线性函数。等式(10-2)和(10-3)称为自治方程。这表示自变量 t 只是以导数的形式出现。于是，在自治系统中，作用力和约束条件都不随时间而变化。

具有直角坐标 x_1 和 x_2 的平面称为相平面或者状态平面。实际上，相平面就是二维的状态空间。

通常，假设系统具有如下较简单形式的微分方程组：

$$\frac{\mathrm{d}x_1}{\mathrm{d}t}=x_2 \tag{10-4}$$

$$\frac{\mathrm{d}x_2}{\mathrm{d}t}=f(x_1,x_2) \tag{10-5}$$

这里，我们定义 $x_1=x$，于是 $x_2=\dot{x}$。最常见的相平面就是 x-$\dot{x}$ 平面。在本课中，除非特别说明，我们提到的相平面都是指 x-$\dot{x}$ 平面。

对具有方程(10-2)和(10-3) 的系统的相平面分析，可以求出任何可能初始条件下系统的概略解。在控制系统中，相平面法特别适合二阶系统的分析和综合，这些二阶系统具有一定的初始条件和/或非周期的输入信号，如阶跃输入、斜坡输入及脉冲输入。

从微分方程解的唯一性的基本原理我们知道，只要联立微分方程组(10-2) 和(10-3) 中的 $f_1(x_1,x_2)$ 和 $f_2(x_1,x_2)$ 解析，则具有某个初始条件的方程(10-2) 和(10-3) 的解是唯一的。(一个函数如果能在某个给定点作傅里叶级数展开，则该函数在该给定点解析)。对于 $f_1(x_1,x_2)=0$ 和 $f_2(x_1,x_2)=0$ 同时成立的点，这种唯一性不成立。这些点称为奇点。奇点通常就是平衡点。在相平面中其他任何点都是普通点。

如果在给定的平衡点附近没有其他平衡点，则该平衡点称为孤立平衡点。尽管许多实际系统仅仅包含孤立平衡点，但是也有一些例外。例如，对于系统

$$\ddot{x}(t)+\dot{x}(t)=0 \tag{10-6}$$

x 轴上的所有点都是平衡点，平衡点不是孤立的。

求取二阶系统的一阶微分方程

从方程(10-2)和(10-3)中消去自变量 t，得

$$\mathrm{d}x_2/\mathrm{d}x_1 = f_2(x_1,x_2)/f_1(x_1,x_2) \tag{10-7}$$

方程(10-7)是 x_2 关于 x_1 的一阶微分方程。并且，这个方程实际上给出了轨迹通过点(x_1,x_2)的切线的斜率。

在任何时间 t，由方程(10-2)和(10-3) [或方程(10-7)]所给出的系统的状态都可以由 x_1 和 x_2 的值来确定。

方程(10-7)的解可以写作

$$x_2=\phi(x_1) \tag{10-8}$$

方程(10-8)表示相平面中的一条曲线，并且表示描述点在曲线上移动的情况。解曲线或轨迹是 x_2 作为 x_1 函数的曲线，它是方程(10-7)所表示的系统的积分曲线。该轨迹没有显示具体的时间信息。当然，如果需要，该轨迹也可以按照时间单位来标定。

相平面图

一簇轨迹就称为相平面图。初始条件决定了描述点在轨迹上的起始位置。随着时间增加，描述点沿着轨迹移动。一个自治系统的相平面表示描述了系统的所有可能状态，系统响应的特性就在相平面图中直接显示出来。由于通过相平面中的任何一个普通点的轨迹有且仅有一根，因此，除奇点以外，由所有可能的初始条件产生的轨迹不会交叉。在奇点上，$\mathrm{d}x_2/\mathrm{d}x_1$ 为 $0/0$ 的形式，因而是不定的。进入和离开一个奇点的轨迹可能有无数条。

对于具有如滞环那样的双值非线性的系统来说，系统就不再是解析的。但在这种情况下，可以将区域分解成为若干个子区域，而系统在每个子区域内是解析的，因此仍然可以使用相平面法。于是，连接每一段解析解就可以得到完整的解。应该注意，当系统的响应是由两个或者更多个二阶微分方程来确定时，轨迹可能会交叉。

如果描述点在 x-$\dot{x}$ 平面的上半平面，随着时间增加，该点在轨迹上向右移动，这是因为速度为正($\dot{x}>0$) 对应着 x 的值随着时间而增加。与此类似，如果一个点在 x-$\dot{x}$ 平面的下半平面，随着时间增加，该点在轨迹上向左运动，这是因为速度为负($\dot{x}<0$) 对应着 x 的值随着时间而减小。于是，在 x-$\dot{x}$ 平面上沿着轨迹运动是按照顺时针方向的。当轨迹穿越 x 轴时，$\dot{x}$ 为零。因此，轨迹将垂直穿越 x 轴。

第 11 课　离散系统和 Z 变换

离散系统或数据采样系统是指一个或多个变量仅在离散的瞬时变化的动态系统。这些瞬时值可以用 kT 或 t_k 表示，指完成测量的时间或者数字计算机内存的读取时间。两个离散时刻的间隔取得很短，这样这些离散时刻之间的数据就可以用简单的插值法近似。

离散系统不同于连续系统，它的信号是采样数据形式。

在实际应用中，当控制所需要的测量以间断的方式进行时，或者当大型的控制器或计算机被多个控制对象所共享，导致传送到每一个控制对象去的控制信号仅为周期性信号时，或者在采用数字计算机去完成控制所必需的计算时，就会产生离散系统。许多现代工业控制系统都是离散的，因为它们总是包含一些输入/输出量在时间上是离散的器件。当然，采样操作或离散化有时完全是假设，其引进目的仅仅是为了简化实际上只包含连续性元件的控制系统的分析。

在本课中，我们将讨论作为控制作用的信号是断续的常量离散系统，且该常量仅在离散的时间点上变化。因为存在几种不同类型且有实用价值的采样运算，我们就将它们列举如下：

(1) 周期(普通)采样：采样时刻的间隔相等，即 $t_k=k\mathrm{T}$ (k=1,2,3) 。

(2) 多级采样：t_k 在形式上周期性地出现，即对于所有的 k，$t_{k+r}-t_k$=常量。

(3) 多速采样：两个同时进行的采样操作分别发生在 $t_k=P\mathrm{T}_1$ 和 $t_k=q\mathrm{T}_2$。其中 p、q 是整数，T_1、T_2 是常数。

(4) 随机采样：采样时刻是随机的，即 t_k 是随机变量。

这里我们只讨论周期采样的情况。

量化 当模拟系统中包含数字计算机时，系统的某一部分就产生数字形式的信号(通常是二进制数)。因此，系统就呈现出数字-模拟式的混合结构形式。在控制系统中引入数字计算机，就要使用数模和模数转换器。因为模拟信号具有无穷多的数值，而由一组确定的数值表示数的数量是有限的，所以，模拟信号转换为相应的数字信号(二进制数)是一种近似。这种近似过程称为量化。

量化的过程(将模拟量转化为数字量)由一些特定的电路来完成。输入量的幅值范围被分为许多有限的区间 h_i，h_i 不一定相等。一个区间的所有幅值都取区间内的唯一值。这个唯一的值就是对模拟输入信号幅度的数字近似。因此，如果 x 为模拟输入，输出的数字值就由 $y=Q(x)$ 确定，其中 Q 为量化函数。

函数 $x(t)$ 是一个离散信号。数字控制系统的操作包括幅值和时间的量化。下面我们介绍一些术语的定义。

转换器：转换器是将输入信号转换为另一种形式输出的装置(输出信号通常取决于输入信号的历史值)。

模拟转换器：模拟转换器是输入和输出信号都是时间的连续函数的转换器。这些信号可以取系统物理限制范围内的任意值。

采样数据转换器：采样数据转换器是输入和输出信号只在离散的瞬间出现的转换器，并且其幅值和模拟转换器的情况一样，未被量化。

数字转换器：数字转换器是输入和输出信号只在离散的瞬间出现的转换器，其幅值是被量化了的，即信号只取特定的离散值。

模拟-数字转换器：模拟-数字转换器的输入信号是连续信号，而输出信号则为量化信号，而且只取特定的离散值。

数字-模拟转换器：数字-模拟转换器的输入信号为量化信号，而输出信号为时间的平滑连续函数。

模拟控制器和数字控制器 就工业控制系统中采用的控制器类型而言，我们可以将它们分为以下3类：

模拟控制器或计算机：模拟控制器或计算机是用连续的物理量表示方程中的变量。模拟控制器可以设计为令人满意的非决策控制器。

数字控制器或计算机：它们仅对数字进行操作。决策是数字控制器的一个重要功能，并常用它们来解决工业对象中总体运行的优化问题。

模拟数字控制器或计算机：它们通常被称为混合控制器，是模拟控制器和数字控制器的一种组合。一些高性能控制器属于这种类型。

数字控制器相对于模拟控制器的优点 数字控制器相对于模拟控制器的优点可以总结如下：

(1) 数字控制器能以一定精度高速地完成复杂的运算。在运算中，数字计算机能在增加较少成本的情况下实现希望的精度。但是，若保持精度不变，运算越复杂，模拟计算机的成本也就越高。

(2) 数字控制器具有很好的通用性。仅仅更新一段程序，就能改变现有操作。如果控制系统接收进行经济分析和优化研究的计算中心发出的操作信息或指令时，这种优点就尤为重要了。

传统的方法不能处理复杂的控制问题，所以它通常是将过程细分为更小的单元，然后分别作为独立的控制问题来处理。人工操作员通常用于协调多个单元的操作。近来，随着计算机控制系统的发展，改变了工业过程控制的这种状况。大型计算机和数学方法的发展为控制系统中利用所有有用信息奠定了基础。传统控制中的这部分控制回路由人工完成。

复杂系统的计算机控制 大规模系统控制当前的发展趋势是将多个独立控制单元合并为一个最优的控制过程。一般来说，由于产品需求、原材料、经济因素、加工设备和方法的变化，工业过程控制系统并不能长时间工作于固定的状态。因此，我们必须考虑工业过程中的动态特性。因为过程变量之间相互影响，所以，每个控制单元只采用一个过程变量，对于真正的全面控制来说是不适当的。通过使用计算机，可以将所有过程变量和经济因素、产品要求、设备性能等都考虑在内，实现工业过程的最优控制。

值得一提的是，一个尽可能全面地控制过程的系统必须能解复杂的方程。越是全面的控制，了解和应用操作变量之间的正确关系就越重要。系统必须能接收诸如计算机和操作员这样的不同信号源所发出的指令，并且能在短时间内改变其控制的子系统。

离散系统分析的Z变换法和状态空间法 离散系统的分析可以很容易采用Z变换法和状态空间法中的任一种。

Z变换与线性定常离散系统的关系，就像是拉氏变换与线性定常连续系统的关系一样。这部分只介绍线性时不变离散系统的Z变换法。

第 12 课　控制系统的状态空间分析

从前面的讨论中我们知道，在处理单输入单输出系统时，根轨迹法和频率响应法是十分有用的。例如，通过开环频率测试，我们可以预测闭环系统的动态性能。如果需要的话，通过插入简单的超前或者滞后补偿器可以改善控制系统的动态性能。传统控制理论的方法概念简单, 计算量合理。

传统控制理论只认为输入、输出和误差信号重要。控制系统的分析和设计借助于传递函数和各种图解方法来完成。这些图解方法包括根轨迹图、奈奎斯特图和伯德图。传统控制理论的独特之处在于它是基于系统的输入-输出关系或传递函数的。

传统控制理论的主要缺点是它只适用于单输入单输出(SISO) 的线性定常(LTI) 系统，不适合处理多输入多输出(MIMO) 系统。并且传统方法(根轨迹法和频率响应法等)不适用于最优控制和自适应控制系统的设计，这些系统大多数是时变的和/或非线性的。

现代工程系统越来越复杂，这主要是因为任务的复杂性和高精度所要求的。复杂系统往往具有多输入多输出并且往往是时变的。由于需要满足对控制系统越来越高的性能要求，以及系统复杂性的增加和大型计算机的使用方便等原因，大约从 1960 年起，现代控制理论这种设计和分析复杂系统的新方法开始发展起来。这一新方法以状态的概念为基础。状态概念本身并不是新的，因为它在经典动力学和其他领域早已存在。(事实上，第 10 课中讨论的相平面就是一个二维状态空间。)

现代控制理论与传统控制理论相比较，前者适用于 MIMO 系统，而 MIMO 系统可能是线性的也可能是非线性的，可能是定常的也可能是时变的，后者仅仅适用于线性定常的 SISO 系统。并且现代控制理论实际上采用的是时域的方法，而传统控制理论采用的是复频域的方法。

使用经典控制理论进行系统设计是一个基于试凑的过程。这种方法无法设计出最优控制系统。另一方面，使用现代控制理论进行系统设计，工程师能根据给定的性能指标设计出最优控制系统。此外，使用现代控制理论可以针对某一类输入进行设计，而不是针对某个特定的输入函数(如脉冲函数、阶跃函数或正弦函数)进行设计。而且，现代控制理论也使工程师在设计时能够将初始条件考虑进去。

在进一步讨论之前，必须定义以下的一些术语：状态、状态空间、状态向量和状态空间。

状态　动态系统的状态是最少的一组变量(称为状态变量)的集合。已知这些变量在 $t=t_0$ 时的值以及 $t\geqslant t_0$ 的输入，就可以完全确定系统在 $t\geqslant t_0$ 的任何时刻的特性。

于是，动态系统在任何时刻 t 的状态仅仅取决于 t_0 时刻的状态和 $t\geqslant t_0$ 以后的输入，并且与 t_0 时刻以前的状态及输入无关。注意，在处理线性定常系统时，我们通常选择参考时刻 t_0 为零。

状态变量　动态系统的状态变量是确定动态系统状态的最少的一组变量。如果至少需要 n 个变量 $x_1(t), x_2(t), \cdots, x_n(t)$ 才能完全描述动态系统的特性(一旦给定 $t\geqslant t_0$ 的输入以及 $t=t_0$ 时刻的初始状态，系统以后的状态就可以完全确定)，这样的 n 个变量 $x_1(t), x_2(t), \cdots, x_n(t)$ 就是一组状态变量。注意，状态变量并不需要是物理上可以测量的量。当然，在实际

中选择容易测量的量作为状态变量就更加方便一些，因为最优控制定理需要适当加权的所有状态变量的反馈。

状态向量　如果需要 n 个状态变量来完全描述一个给定系统的特性，则这 n 个状态变量可以看成是状态向量 $X(t)$ 的 n 个分量。这样的向量称为状态向量。于是，状态向量就是这样一个向量，当系统输入 $u(t)$ (其中 $t \geqslant t_0$)一旦确定之后，它就唯一地确定系统的状态 $X(t)$。

状态空间　以 $x_1(t)$ 轴、$x_2(t)$ 轴、…以及 $x_n(t)$ 轴为坐标轴的 n 维空间称为状态空间。系统的任何状态可以由状态空间中的一个点来表示。

一个现代控制系统可以有许多输入和许多输出，它们之间可能存在复杂的相互关联。要分析这样的系统，主要是要降低数学表达的复杂性，并用计算机来做绝大部分在分析中必要而繁琐的计算工作。从这种观点来看，系统分析的状态空间法最为适合。

传统的控制理论是基于输入-输出关系或传递函数的，而现代控制理论则是基于系统的方程表示。系统方程用 n 个一阶微分方程来表示，它们可以合并成一个一阶的向量-矩阵微分方程。采用向量-矩阵表示大大地简化了系统的数学表示形式。状态变量、输入个数或输出个数的增加并不增加方程的复杂程度。实际上，分析复杂的 MIMO 系统可以按照一定步骤进行，而这种步骤只比用来分析一阶标量微分方程的步骤稍微复杂一点。

从计算的观点来看，因为状态空间法是时域的方法，所以特别适合使用数字计算机运算。这样就把工程师从繁琐的计算负担中解放出来，使他们可以将精力完全集中在分析问题方面。这是状态空间法的一大优点。

最后应该着重指出的是，状态变量并非一定要表示系统的物理量。不表示物理量的变量和那些既不能测量也不能观测的变量，也可以被选作状态变量。选择状态变量的灵活性是状态空间法的另一大优点。

第 13 课　李雅普诺夫稳定性分析的介绍

对于一个给定的控制系统，稳定性通常是需要确定的一个重要问题。如果系统是线性定常的，那么很多稳定性判据可用于稳定性分析，如奈奎斯特稳定性判据和劳思稳定性判据等。但是，如果系统是非线性的，或是线性但为时变的，那么这些稳定性判据就不再适用。虽然奈奎斯特稳定性判据可以用于某些特殊类型的非线性系统，但是，描述函数法对于确定稳定性问题仅仅是近似的。建立在相平面法基础之上的稳定性分析也只能用于一阶和二阶系统。

李雅普诺夫第二方法(也称为李雅普诺夫直接法)是确定非线性和/或时变系统稳定性的最一般的方法。这种方法可应用于任意阶的系统。

通过使用李雅普诺夫的第二方法，我们可以不用解出状态方程的解而确定一个系统的稳定性。因为求解非线性和/或时变的状态方程通常很困难，所以这种方法就显出很大的优越性。

虽然使用李雅普诺夫第二方法需要相当多的经验和技巧，但是当其他方法无效时，它能解决一些非线性系统的稳定性问题。

本课的目的是介绍李雅普诺夫第二方法，并且阐述它在线性和非线性系统的稳定性分

析中的应用。

在这一节中，首先我们给出系统、平衡状态、稳定性、渐近稳定性和不稳定性的定义。然后定义标量函数的定性，半定性和不定性。

系统　在这一节中，我们研究的系统定义为

$$\dot{\boldsymbol{x}}=\boldsymbol{f}(\boldsymbol{x}, t) \tag{13-1}$$

式中 $\boldsymbol{x}$ 是一状态向量(n 维向量)，$\boldsymbol{f}(\boldsymbol{x}, t)$是 n 维向量，它的各元素是 $x_1, x_2, ...x_n$ 和 t 的函数。我们假定在给定的初始条件下方程(13-1)有唯一解。

我们假定方程(13-1) 的解为$\phi(t;x_0,t_0)$。其中当 $t=t_0$ 时，$x=\boldsymbol{x}_0$，t 是观察的时间。于是：

$$\phi(t_0; \boldsymbol{x}_0, t_0) =\boldsymbol{x}_0$$

平衡状态　在方程(13-1) 的系统中，对于所有 t，总存在着

$$\boldsymbol{f}(\boldsymbol{x}_e, t) =0 \tag{13-2}$$

则称状态 x_e 为系统的平衡状态。如果系统是线性定常的，即 $\boldsymbol{f}(\boldsymbol{x}, t) =\boldsymbol{A}\boldsymbol{x}$，如果矩阵 A 是非奇异矩阵，则系统只有一个平衡状态；若 A 是奇异矩阵，则系统存在无穷多个平衡状态。对于非线性系统来说，可有一个或多个平衡状态。这些状态对应于系统(对所有 t，$\boldsymbol{x}=\boldsymbol{x}_e$)的常值解。平衡状态的确定不涉及系统微分方程(13-1) 的解，而只涉及方程(13-2) 的解。

任何一个孤立的平衡状态(例如彼此孤立的平衡状态)通过坐标转换可以移到坐标原点或者 $\mathbf{f}(\mathbf{0},t) =\mathbf{0}$ 处。在这一节里，我们将只讨论这种状态的稳定性分析。

李雅普诺夫意义下的稳定　下面，我们将在平衡状态 $\boldsymbol{x}_e$ 周围，半径为 k 的球域表示为：

$$\| x-\boldsymbol{x}_e \| \leqslant k$$

式中 $\| \boldsymbol{x}-\boldsymbol{x}_e \|$ 叫做欧几里德范数，定义为

$$\| \boldsymbol{x}-\boldsymbol{x}_e \| = [(x_1-x_{1e})^2+(x_2-x_{2e})^2+\ldots+(x_n-x_{ne})^2]^{1/2}$$

设 $S(\delta)$ 是包含使

$$\| \boldsymbol{x}-\boldsymbol{x}_e \| \leqslant \delta$$

的全部点的一个球域，而 $S(\varepsilon)$ 是包含使

$$\| \phi(t;\boldsymbol{x}_0,t_0) -\boldsymbol{x}_e \| \leqslant \varepsilon \quad t\geqslant t_0$$

的全部点的一个球域。

如果对于每一个 $S(\varepsilon)$，对应存在一个 $S(\delta)$，使得当 t 无限增加时，从 $S(\delta)$出发的轨迹不离开 $S(\varepsilon)$，则方程(13-1)的系统的平衡状态 $\boldsymbol{x}_e$ 在李雅普诺夫意义下是稳定的。实数δ与ε有关，通常也与 t_0 有关。如果δ与 t_0 无关，那么这种平衡状态是一致稳定的。

以上我们阐述的就是：首先选择 $S(\varepsilon)$域，而对于每一个 $S(\varepsilon)$，必然对应存在着一个 $S(\delta)$ 域，使得当 t 无限增加时，在 $S(\delta)$内出发的轨迹总不离开 $S(\varepsilon)$域。

渐近稳定性　如果平衡状态 $\boldsymbol{x}_e$ 在李雅普诺夫意义下是稳定的，并且从 $S(\delta)$域出发的任意一个解在 t 无限增加时都不离开 $S(\varepsilon)$，而是收敛于 $\boldsymbol{x}_e$，那么方程(13-1)的系统的平衡状态 $\boldsymbol{x}_e$ 是渐近稳定的。

在实际应用当中，渐近稳定性比单纯的稳定性更重要。同时由于渐近稳定性是一个局部的概念，所以只确定渐近稳定性并不意味着系统就能正常工作。确定渐近稳定性的最大范围通常是很有必要的。这个范围称为吸引范围。它是引出渐近稳定轨迹的状态空间的一部分。换句话说，起始于这个吸引范围的每条轨迹都是渐近稳定的。

大范围内的渐近稳定性　对所有的状态(状态空间中的所有各点)，如果由这些状态出发的轨迹都保持渐近稳定，那么就认为平衡状态在大范围内是渐近稳定的。也就是说，如果方程(13-1)是稳定的，而且它的每一个解在 t 趋于无穷大时都收敛于 $\boldsymbol{x}_e$，那么就认为系统的平衡状态 $\boldsymbol{x}_e$ 在大范围内渐近稳定。很明显，大范围内渐近稳定的必要条件是在整个状态空间中只有一个平衡状态。

在控制工程问题中，总是希望系统具有大范围内渐近稳定的特性。如果平衡状态不是在大范围内渐近稳定的，那么问题就转化为确定渐近稳定的最大范围，这通常是很困难的。但是，如能实际确定一个不被扰动超过的足够大的渐近稳定范围，也就足够了。

不稳定性　如果对于某个实数 $\varepsilon>0$ 和 $\delta>0$，不管多么小，在 $S(\delta)$内总存在着一个状态 $\boldsymbol{x}_0$，使得由这一状态出发的轨迹离开 $S(\varepsilon)$，那么就认为平衡状态 $\boldsymbol{x}_e$ 不稳定。

稳定性、渐近稳定性和不稳定性的图形表示　用图形表示时，可使上述各个概念更为清晰。

我们来研究二维平面的情况。图 13.1(a)、图 13.1(b)和图 13.1(c)分别表示平衡状态和对应于稳定、渐近稳定和不稳定的典型轨迹。在图 13.1(a)、图 13.1(b)或图 13.1(c)中，$S(\delta)$域限制初始状态 $\boldsymbol{x}_0$ 的范围，而 $S(\varepsilon)$ 域是起始于 $\boldsymbol{x}_0$ 的轨迹的边界。

注意　上述定义并不能详细地说明可容许初始条件的准确范围。除非 $S(\varepsilon)$对应于整个状态平面，否则这些定义只适用于平衡状态的邻域。

注意　图 13.1(c)中的轨迹离开了 $S(\varepsilon)$，这就说明平衡状态不稳定。但我们不能说轨迹将趋于无穷远处，这是因为轨迹还可能趋于在 $S(\varepsilon)$ 外的某个极限环。(如果一个线性定常系统是不稳定的，那么起始于不稳定平衡状态附近的轨迹会趋于无穷远。但是，在非线性系统中，这并不一定是正确的。)

上述各个定义对于理解本节介绍的线性和非线性系统的稳定性分析，都是最低限度的知识。注意，这些概念并不是定义平衡状态稳定性的唯一方法。实际上，在其他文献中还有另外的定义。例如，在经典控制理论中，只有渐近稳定的系统被称为稳定系统。而那些在李雅普诺夫意义下是稳定的系统，但不是渐近稳定的，就称为不稳定系统。

标量函数的正定性　如果对于所有在 Ω 域中的非零状态 x，有 $V(x)>0$，而且 $V(0)=0$，那么在 Ω 域 (包括状态空间的原点)中的标量函数 $V(x)$称为是正定的。

如果时变函数 $V(\boldsymbol{x},t)$由一个定常的正定函数作为下限，即存在一个正定函数 $V(\boldsymbol{x})$，使得

$$V(x,t)>V(x)\qquad t\geqslant t_0$$
$$V(0,t)=0\qquad t\geqslant t_0$$

那么，我们称时变函数 $V(x,t)$ 在 Ω 域(包括状态空间的原点)内是正定的。

标量函数的负定性　如果$-V(\boldsymbol{x})$ 是正定的，则标量函数 $V(\boldsymbol{x})$ 是负定的。

标量函数的半正定性　如果标量函数 $\boldsymbol{V(x)}$ 除了原点以及某些状态等于零外，在 Ω 域内的所有状态都是正定的，那么标量函数 $\boldsymbol{V(x)}$ 就称为半正定标量函数。

标量函数的负半定性　如果$-V(\boldsymbol{x})$是半正定的，则标量函数 $V(\boldsymbol{x})$是半负定的。

标量函数的不定性　如果在 Ω 域内，不管 Ω 域多么小，标量函数 $V(\boldsymbol{x})$既可为正值也可为负值，那么 $V(\boldsymbol{x})$ 是不定的标量函数。

第 14 课　最优控制系统介绍

最优控制系统　近十年来，由于对高性能系统需求的增长和数字计算机的使用方便，最优控制问题受到了极大关注。

控制系统优化的概念包括性能指标的选择和在物理条件限制下最优控制系统的设计这两部分。最优控制系统和理想最优控制系统的差别在于前者是在物理条件限制的情况下可达到的最好结果，而后者是不可能达到的目标。

性能指标　在解决最优控制系统的问题时，我们有可能找到一个确定现有控制策略的规则，在某些约束条件下使它偏离理想状态的偏差测量值达到极小。这种测量值通常根据优化原则或性能指标来确定。性能指标是一个函数，其数值表示系统的实际性能与期望的性能接近的程度。在大多数实际应用中，可以通过选择控制向量，使性能指标达到极小(或极大)的方法使系统性能达到最优。

因为性能指标在很大程度上确定了所设计的最优控制的性能，所以它很重要。也就是说，得到的控制可能是线性的、非线性的、定常的或者时变的，而这些都取决于性能指标的形式。控制工程师根据问题的要求，用公式来表示性能指标。因此，它影响产生的系统的特性。当然，对控制问题的要求不仅包括性能要求，而且也包括保证物理上可实现的对控制形式的限制条件。

优化过程不仅提供最优控制策略和最优参数配置，还提供在应用非最优策略的条件下，性能指标函数偏离它的极小(或极大)值时也能衡量性能上降低的程度。

在系统设计时，优化理论应用于选择性能指标，在很大程度上要受到分析的可能性与实际应用之间的矛盾的阻碍。最优控制准则不仅要从数学上来考虑，而且还要从应用的角度来考虑。当然，性能指标的选择通常应该在既能对系统的性能作有意义的估计，又考虑数学上易于处理这两个方面之间采取折衷。

对于一个给定的要求，要选择一个最合适的性能指标是很难的，尤其是对于复杂的系统。例如，我们考虑宇宙飞船有效载荷达到极大的问题。有效载荷可认为是完成任务后飞船的重量和飞船其余部分之间的差值，例如支撑结构、通信设备、能源设备和高度控制装置。所以，为了使有效载荷达到极大，涉及的方面就包括为消耗最少推进剂选择最优的推力程序和任务设计以及飞船每一部件的最优设计。在宇宙飞船的应用中，其他的一些性能指标可以是燃料消耗量最小、脱靶量最小、时间最短等。与军用的不同，民用控制系统考虑的通常主要是经济性。

优化问题的数学描述　控制系统优化问题中出现的量有状态变量、控制变量和系统参数。例如，研究一艘飞船时，可把它看作在空间飞行的一个质点。这个系统的状态变量就是飞船的 3 个位置坐标、3 个速度坐标和飞船的瞬时质量。本例中，这些状态变量可从一组微分方程中得到，微分方程可简单地表示成牛顿运动方程组及与飞船质量损失率有关的推进剂流量的连续方程。本例中的控制变量可能是飞船推力的大小和一组确定推力方向的角度。系统的参数是描述问题某些性质的一些常量。这些参数可以是推进系统的排出速度或者预先确定的推进终止时间。对于应用离子推进的系统，这些参数可以是排出速度值和飞船携带的能源装置的尺寸。

通常，如果下面的条件已给出，那么控制系统的优化问题就可用公式表示出来。

(1) 系统的状态方程和输出方程；

(2) 控制向量；

(3) 问题的约束条件；

(4) 性能指标；

(5) 系统参数。

最优控制问题就是在所有可能的控制向量中确定最优控制向量 $\boldsymbol{u}(t)$。向量 $\boldsymbol{u}(t)$ 通常取决于初始状态或者初始输出、期望的状态或者期望的输出、约束的性质以及性能指标的性质。

除特殊情况外，最优控制问题的解析解都很复杂，因此必须求其数值解。在本节中，我们将讨论时间最优控制系统和基于二次型性能指标的最优控制系统。

时间最优控制系统　接下来我们将讨论两类时间最优控制问题。其中一类是给定如下离散时间系统：

$$\boldsymbol{x}((k+1)T) = \boldsymbol{G}(T)\boldsymbol{x}(kT) + \boldsymbol{H}(T)\boldsymbol{u}(kT)$$

来求以最少的采样周期数，使初始状态转移到状态空间原点的控制向量 $u(kT)$ ，式中 $u(kT)$ 的模是无界的。

最优控制系统的几点说明　按定义使所选的性能指标达到极小(或极大)的系统是最优的。显然，性能指标实际上确定了系统的结构。应当着重指出的是，在给定性能指标下的一个最优控制系统，在其他性能指标下一般就不是最优的。此外，用硬件来实现具体的最优控制规律可能非常困难且昂贵。因此，为实现某些狭义上为最好的最优控制器而花费大量费用是毫无意义的。一个控制系统的设计很少是为了完成事先完全确定的单一任务，而是完成从所有可能任务中随意选择的一个任务。在实际系统中，确定并不局限于单一性能指标的近似的最优控制规律，可能更切合实际一些。

严格地说，我们应认识到，在大多数实际应用中，用数学工具建立的最优控制系统，确定了在给定性能指标下的最终性能极限，而且与其说是实际的目标，不如说是一个衡量的标准。因此，在决定构建最优控制系统或者决定构建性能上较差、但比较简单的控制系统之前，我们应该仔细地权衡复杂的最优控制系统优于简单的次优控制系统程度。除非最优控制系统经过充分论证，否则我们不会去构建一个极其复杂的最优控制系统。

一旦应用最优控制理论求得最终性能极限后，我们就尽量设计一个接近最优系统的简单系统。应当记住，我们可建立一个物理系统的样件，试验并进行修改，直到获得一个性能指标接近用最优控制理论综合出的最优控制系统的满意系统时为止。

关于最优控制问题的解存在性的一些问题　前面已经说明了，给定任一初始状态 $\boldsymbol{x}(t_0)$ ，最优控制问题就是求一个可能的控制向量 $\boldsymbol{u}(t)$，将该状态转移到状态空间中所希望的区域中，使得性能指标达到极小。

应当着重指出的是，在某些情况下，对象的特定组合、期望状态、性能指标以及约束条件会导致最优控制不能实现，这是一个性能要求超过系统物理能力的问题。

关于最优控制系统存在性的问题也很重要，因为它们能告诉设计者，提出的性能指标对于一个给定的系统和一组约束条件，是不是可能实现。其中最重要的两个问题是可控性和可观性。以下我们将简要地解释一下可控性和可观性的含义。

可控性和可观性　在有限的时间间隔内，如果可以用一个无约束的控制向量将系统从初始状态 $\boldsymbol{x}(t_0)$ 转移到另一个状态，那么就认为该系统在 t_0 时刻是可控的。

在有限的时间间隔内，对于处于状态 $\boldsymbol{x}(t_0)$ 的系统，如果其状态可通过输出的观测值确定，那么就认为该系统在 t_0 时刻是可测的。

可控性和可观性的概念是卡尔曼提出的。在多变量最优控制系统中，这两个概念具有重要的作用。事实上，可控性和可观性可以确定最优控制问题通解存在的条件。

第 15 课　传感器的介绍

这是对仪表系统中传感器物理原理的介绍。这里并没有准备给出权威性或详尽的说明，仅仅是告诉读者对于不同系统可实现的简易途径。我很高兴收到改进的批评和建议。

电阻具有最简单的电气特性，能以低廉的成本在很大的范围内实现精确的测量。一个简单的价值几十美元的数字万用表使用两线技术能够测量范围从 10 欧姆到 10 兆欧姆的电阻，精度可达到 1%，如图 15.1 所示。

两线法的精度由于导线电阻 R_{L1} 和 R_{L2} 不确定的阻值而受到限制。

如果 R_{L1} 和 R_{L2} 能很好匹配，就能够使用三线法。图 15.2 中的电路使用了两个匹配的电流源 I1 和 I2 来消除引线电阻的影响。图 15.3 中的电路是 AC 电桥，当 R_X=R_Y 时，电路处于平衡状态。如果把锁定放大器作为检零器，用极低的激励电流就能确定 R_X。

四线“开尔文”法(图 15.4 中的电路)用于一些难于处理的情况，如引线电阻变化，RX 非常小或者需要很高的精度。这种方法不受引线电阻的影响，但受恒流源和电压测量特性的限制。改变激励电流的极性，求两次测量的平均值，就可以消除热电势。

电阻式温度检测器的特性表明，金属和合金的电阻率随着温度变化而呈现重复性的变化。温度系数为 0.0039 K^{-1} 的铂是应用中最常用的材料。RTD 由线匝或薄膜组成，采用四线连接，兼有较好的可靠性和热稳定性。RTD 在很宽的温度范围内具有很好的精度(例如 0.025K 的室温)。金属在低温下的阻值是不变的，并且经常用一部分掺杂半导体作为敏感元件。使用 RTD 时，确定被测电阻独立于激励电流很重要，以避免由自热引起的误差。

应变仪

在恒温下，面积为 A 的、长度为 l、电阻系数为 ρ 的金属或者半导体元件的阻值 R 是

$$R = l\rho/A \tag{15-1}$$

元件受力后的变化量为：

$$\Delta R = \left[\frac{\partial R}{\partial \mathrm{l}}\right]\Delta \mathrm{l} + \left[\frac{\partial R}{\partial \rho}\right]\Delta\rho + \left[\frac{\partial R}{\partial \mathrm{A}}\right]\Delta \mathrm{A} = \frac{\rho}{\mathrm{A}}\Delta \mathrm{l} + \frac{\mathrm{l}}{\mathrm{A}}\Delta\rho + \frac{\rho \mathrm{l}}{\mathrm{A}^2}\Delta A$$
$$\therefore \frac{\Delta R}{\mathrm{R}} = \frac{\Delta \mathrm{l}}{\mathrm{l}} + \frac{\Delta\rho}{\rho} - \frac{\Delta \mathrm{A}}{\mathrm{A}} \tag{15-2}$$

典型的应变仪由金属箔和光刻技术形成一种弯曲的形状，并固定在树脂底片上。然后用黏和剂固定在设备上以便监测。在上述方程中，金属传感元件是受几何参数控制的，因此它们相对地独立于温度，并且有适当的灵敏系数(例如敏感度)，大约为 2。半导体元件能够利用显著的压阻效应产生 150 左右灵敏系数。但这在实际中是以温度的稳定性为代价的，

并且需要采用特定形式的补偿方法。

应变仪的应用广泛。它们小巧、便宜、灵敏并且可靠，同时许多变量(例如压力)能够产生形变。

电容也能够以低廉的成本在很大的范围内进行测量。一个简单的便携式仪表和几个数字万用表采用两线技术可测量范围在 100 皮法到 1 法的电容，精度可达到 1%。这类仪表经常将未知电容并入到弛张振荡器中进行工作，如锯齿波发生器实验。这样用已知的恒定电流对未知电容进行充电，根据将电容充电到阈值电压所需的时间来计算出电容。

杂散电容是电容测量中的主要误差来源，其典型值在 10 pF 到 10 nF 之间，必须采用“隔离”技术进行处理。通过特定的方法用保持同样电压的导线将高阻端子包围起来可以实现隔离。图 15.5 表明，通过将屏蔽层接到低阻节点，可消除连接到同轴电缆上对地的杂散电容的影响。

在小心的情况下(以及价值大约1万美元的设备)，采用“AC同轴电桥”可测量$1/10^8$的绝对电容。

电容传感器是所有电类传感器中最精确的，电容传感器可设计成：

(1) 无能耗的，因此没有热噪音；

(2) 无自热；

(3) 与所加电压成线性关系；

(4) 与温度无关。

简单而非常精确的传感器是基于一对电容极板几何面积的变化，或是向电容器空隙加入电导材料。

电容压力传感器使用了一个薄的隔膜，通常是金属或者涂了金属的石英作为电容器的一个极板。隔膜的一边接触被测压力，另外一边接触参考压力。压力的变化引起形变，从而改变电容。这种变化可能与压力是线性关系，也可能不是，而且也只是总电容的一小部分。利用电容控制振荡器的频率或者改变交流信号的耦合就能够检测出其参数。将信号调节电路紧靠传感器，以便减小杂散电容的不利影响，这是好习惯。图 15.6 中的电路就是一个示例。

基于硅材料的微机电技术的发展大大地提高了电容压力传感器的性能和实用性。

第 16 课　PID 控制器的介绍

PID 控制器可以是独立控制器(也可以叫做单回路控制器)，可编程控制器(PLCs)中的控制器，嵌入式控制器或者是用 Vb 或 C#编写的计算机程序软件。

PID 控制器是过程控制器，它具有如下特征：

- 连续过程控制；
- 模拟输入(也被称为“测量量”或“过程变量”或“PV”)；
- 模拟输出(简称为“输出”)；
- 基准点(SP)；
- 比例、积分以及/或者微分常数；

“连续过程控制”的例子有温度、压力、流量及水位控制。例如。控制一个容器的热

量。对于简单的控制，你使用两个具有温度限定功能的传感器(一个限定低温，一个限定高温)。当低温限定传感器接通时就会打开加热器，当温度升高到高温限定传感器时就会关闭加热器。这类似于大多数家庭使用的空调及供暖系统的温度自动调节器。

反过来，PID 控制器能够接受像实际温度这样的输入，控制阀门，这个阀门能够控制进入加热器的气体流量。PID 控制器自动地找到加热器中气体的合适流量，这样就保持了温度在基准点稳定。温度稳定了，就不会在高低两点间上下跳动了。如果基准点降低，PID 控制器就会自动降低加热器中气体的流量。如果基准点升高，PID 控制器就会自动的增加加热器中气体的流量。同样地，对于高温，晴朗的天气(当外界温度高于加热器时)及阴冷，多云的天气，PID 控制器都会自动调节。

模拟输入(测量量)也叫做“过程变量”或“PV”。你希望 PV 能够达到你所控制过程参数的高精确度。例如，如果我们想要保持温度为+1 度或−1 度，我们至少要为此努力，使其精度保持在 0.1 度。如果是一个 12 位的模拟输入，传感器的温度范围是从 0 度到 400 度，我们计算的理论精确度就是 4096 除 400 度=0.097656 度。我们之所以说这是理论上因为我们假定温度传感器，电线及模拟转换器上没有噪音和误差。还有其他的假定。例如，线性等等。即使是有大量的噪音和其他问题，按理论精确度的 1/10 计算，1 度精确度的数值应该很容易得到的。

模拟输出经常被简称为“输出”。经常在 0%到 100%之间给出。在这个热量的例子中，阀门完全关闭(0%)，完全打开(100%)。

基准点(SP)很简单，即你想要什么样的过程量。在这个例子中—你想要过程处于怎样的温度。

PID 控制器的任务是维持输出在一个程度上，这样在过程变量(PV)和基准点(SP)上就没有偏差(误差)。

在图 16.1 中，阀门用来控制进入加热器的气体，冷却器的制冷，水管的压力，水管的流量，容器的水位或其他的过程控制系统。

PID 控制器所观察的是 PV 和 SP 之间的偏差(或误差)。它观察绝对偏差和偏差变换率。绝对偏差就是——PV 和 SP 之间偏差大还是小。偏差变换率就是——PV 和 SP 之间的偏差随着时间的变化是越来越小还是越来越大。

如果存在过程扰动，即过程变量或基准点变化时——PID 控制器就要迅速改变输出，这样过程变量就返回到基准点。如果你有一个 PID 控制的可进入的冷冻装置，某个人打开门进入，温度(过程变量)将会迅速升高。因此，PID 控制器不得不提高冷度(输出)来补偿这个温度的升高。

一旦过程变量等同于基准点，一个好的 PID 控制器就不会改变输出。你所要的输出就会稳定(不改变)。如果阀门(发动机或其他控制元件)不断改变，而不是维持恒量，这将造成控制元件更多的磨损。

这样就有了两个矛盾的目标。当有“过程扰动”时能够快速反应(快速改变输出)。当 PV 接近基准点时就缓慢反应(平稳输出)。

我们注意到输出量经常超过稳定状态输出使过程变量回到基准点。比如，一个制冷器通常打开它的制冷阀门的 34%，就可以维持在零度(在制冷器关闭和温度降低后)。如果某人打开制冷器，走进去，四处走，找东西，然后再走出来，再关上制冷器的门——PID 控

制器会非常活跃，因为温度可能将上升 20 度。这样制冷阀门就可能打开 50%，75%甚至100%——目的是赶快降低制冷器的温度——然后慢慢关闭制冷阀门到它的 34%。

让我们思考一下如何设计一个 PID 控制器。

我们主要集中在过程变量(PV)和基准点(SP)之间的偏差(误差)上。有三种定义误差的方式。

绝对偏差

他说明的是 PV 和 SP 之间的偏差有多大。如果 PV 和 SP 之间偏差小——那我们就在输出时作一个小的改变。如果 PV 和 SP 之间偏差大——那我们就在输出时作一个大的改变。绝对偏差就是 PID 控制器的比例环节。

累积误差

给我们点儿时间，我们将会明白为什么仅仅简单地观察绝对偏差(比例环节)是一个问题。累积误差是很重要的，我们把它称为是 PID 控制器的积分环节。每次我们运行 PID 算法时，我们总会把最近的误差添加到误差总和中。换句话说，累积误差=误差 1＋误差 2＋误差 3＋误差 4＋…。

滞后时间

滞后时间指的是 PV 引起的变化由发现到改变之间的延时。典型的例子就是调整你的烤炉在合适的温度。当你刚刚加热的时候，烤炉热起来需要一定时间。这就是滞后时间。如果你设置一个初始温度，等待烤炉达到这个初始温度，然后你认为你设定了错误的温度，烤炉达到这个新的温度基准点还需要一段时间。这也就被认为是 PID 控制器的微分环节。这就抑制了某些将来的变化因为输出值已经发生了改变，但并不是受过程变量的影响。

绝对偏差/比例环节

有关设计自动过程控制器，人们最初想法之一是设计比例环节。意思就是,如果 PV 和 SP 之间的偏差很小——那么我们就在输出处作一个小的修改;如果 PV 和 SP 之间的偏差很大——那么我们就在输出处作一个大的修改。当然这个想法是有意义的。

我们在 Microsoft Excel 仅对比例控制器进行仿真。图 16.2 是显示首次仿真结果的表格。(滞后时间＝0，只含比例环节)

比例、积分控制器

PID 控制器中的积分环节是用来负责纯比例控制器中的补偿问题的。我们有另外一个 Excel 的扩展表格，表格上仿真的是一个具有比例积分功能的 PID 控制器。这里(Fig.16.3)是比例积分控制器最初的仿真表格(滞后时间＝0，比例常数＝0.4)。

众所周知，比例积分控制器要比仅有比例功能的比例控制器好得多，但是等于 0 的滞后时间并不常见。

微分控制

微分控制器考虑的是：如果你改变输出，那么要在输入(PV)处反映这个改变就需要些时间。比如，让我们拿烤炉的加热为例。

如果我们增大气体的流量，那么从产生热量，热量分布烤炉的四周，到温度传感器检测升高的温度都将需要时间。PID 控制器中微分环节具有抑制功能，因为有些温度增量会在以后不需要的情况下产生了。正确地设置微分系数有利于你对比例系数和积分系数的确定。

第 17 课　过程控制简介

过程控制系统　自动过程控制系统是指将被控量为温度、压力、流量、成份等类型的过程变量保持在理想的运行值的系统。过程实际上是动态的。变化总是会出现，此时如果不采取相应的措施，那些与安全、产品质量和生产率有关的重要变量就不能满足设计要求。

为了说明问题，让我们来看一下热交换器。流体在这个过程中被过热蒸汽加热，如图 17.1 所示。

这一装置的主要目的是将流体由入口温度 $T_i(t)$ 加热到某一期望的出口温度 $T(t)$ 。如前所述，加热介质是过热蒸汽。

只要周围没有热损耗，过程流体获得的热量就等于蒸汽释放的热量，即热交换器和管道间的隔热性很好。

很多变量在这个过程中会发生变化，继而导致出口温度偏离期望值。如果出现这种情况，就该采取一些措施来校正偏差，其目的是保持出口温度为期望值。

实现该目的的一种方法是首先测量 $T(t)$，然后与期望值相比较，由比较结果决定如何校正偏差。蒸汽的流量可用于偏差的校正。就是说，如果温度高于期望值，就关小蒸汽阀来减小进入换热器的蒸汽流量；若温度低于期望值，就开大蒸汽阀，以增加进入换热器的蒸汽流量。所有这些操作都可由操作员手工实现，操作很简单，不会出现什么问题。但是，由于多数过程对象都有很多变量需要保持为某一期望值，就需要许多的操作员来进行校正。因此，我们想自动完成这种控制。就是说，我们想利用无需操作人员介入就可以控制变量的设备。这就是所谓自动化的过程控制。

为达到上述目标，就需要设计并实现一个系统。图 17.2 所示为一个可行的控制系统及其基本构件。首先要做的是测量过程流体的出口温度，这一任务由传感器(热电偶、热电阻等)完成。将传感器连接到变送器上，由变送器将传感器的输出信号转换为足够大的信号传送给控制器。控制器接收与温度相关的信号并与期望值比较。根据比较的结果，控制器确定保持温度为期望值的控制作用。基于这一结果，控制器再发一信号给执行机构来控制蒸汽流量。

下面介绍控制系统中的 4 种基本元件，分别是：

(1) 传感器，也称为一次元件。

(2) 变送器，也称二次元件。

(3) 调节器，控制系统的“大脑”。

(4) 执行机构，通常是一个控制阀，但并不全是。其他常用的执行机构有变速泵、传送装置和电动机。

这些元件的重要性在于它们执行每个控制系统中都必不可少的 3 个基本操作，即：

(1) 测量：被控量的测量通常由传感器和变送器共同完成。

(2) 决策：根据测量结果，为了维持输出为期望值，控制器必须决定如何操作。

(3) 操作：根据控制器的处理，系统必须执行某种操作，这通常由执行机构来完成。

如上所述，每个控制系统都有 M、D 和 A 这 3 种操作。

有些系统的决策任务简单，而有些很复杂。设计控制系统的工程师必须确保所采取的操作能影响被控变量，也就是说，该操作要影响测量值。否则，系统是不可控的，还会带来许多危害。

自动过程控制的重要术语　定义自动过程控制领域的一些术语很有必要。第一个是被控变量。它是指必须维持或控制在某一期望值的变量。在前面的例子中，过程出口温度 $T(t)$ 即为被控变量。第二个是设定值，被控变量的期望值。控制变量是用于将被控变量保持在设定值的变量。在上例中，蒸汽流量是控制量。最后，任何使被控变量偏离设定值的变量称为干扰或扰动。多数过程中都存在各种不同的扰动。在图 17.1 所示的换热器中，可能的扰动有入口温度 $T_i(t)$、入口流量 $q(t)$、蒸汽质量、环境条件、流体的成分和结垢等。在加工工业中，自动化的过程控制通常需要扰动的存在，明确这一点很重要。如果没有扰动，设计运行条件不变，那就没有必要不停地对过程进行“调节”。

重要的术语还有下面这些。开环是指被控过程与控制器分离的情况，即控制器并不采取任何操作将被控变量维持在设定值。开环控制中存在的另一种情况是，控制器产生的动作对检测没有影响。在控制系统的设计中，这是主要的缺点。闭环控制是指控制器被连在过程中，被控变量与设定值比较后产生校正作用。

根据这些定义的概念，自动过程控制系统的任务可以阐述如下：一个自动过程控制系统的任务是在出现扰动时利用控制量将被控量维持在设定值。

调节和伺服控制　在一些过程中，被控量由于受到干扰而偏离一个固定的设定值。调节控制是指设计系统来补偿扰动。在其他一些情况下，最主要的干扰是设定值本身，即设定值随时间而变化(典型的是批处理过程)，被控变量就必须随设定值而变化。伺服控制就是为此目的而设计的控制系统。

在工业过程中，调节控制比伺服控制更普遍，但其基本设计方法实际上一样。因此，自动过程控制中的许多原理对两者都适用。

传输符号　现在我们介绍一些控制系统中用于仪表之间通信的符号的词汇。工业过程中现在常用的符号主要有 3 种类型。气动信号或气压的范围是 3~15 磅/平方英寸(表压)，很少使用 6~30 或 3~27 的表压。管道和仪表安装图中的气压符号是—//—//—。电信号为 4~ 20mA，很少使用 10~50mA、1~5V 或 0~10V。在设备安装图中的符号是------。第三种日渐普及的信号是数字或离散信号(0 和 1)。基于大型计算机、微机或微处理器的过程控制系统的应用促进了这类信号的广泛使用。

将一种信号转换为另一种类型通常是必要的，这是通过转换器实现的。例如，经常需要将电信号(毫安)转换为气动信号(表压)，这就要用将电流变为气压的 I/P 转换器。输入信号为 4~20 mA，输出信号为 3~15 psig。其他类型的转换器还有很多，如气压-电流(P/I)、电压-气压(E/P)和气压-电压(P/E)等。

过程控制需要的背景知识　为了很好地实现自动过程控制，工程师首先必须掌握工艺过程的原理。在研究过程自动控制时，掌握过程的动态特性也很重要。因此，建立描述不同过程的方程组也很必要，即所谓建模。要做到这一点，就需要掌握前面介绍的基本原理和列微分方程的数学知识。在过程控制中，拉氏变换很有用，它可以大大简化微分方程的求

解及过程与控制系统的动态分析。

过程控制研究和实践的另一重要工具是计算机仿真。许多为描述过程而建立的方程实际上是非线性的，因此，解决问题最精确的方法就是数值方法，即用计算机求解。过程模型的计算机求解就称为仿真。

第 18 课　智 能 控 制

智能与智能系统能用许多方式和从许多方面来描述。通常包含智能系统的特征，这些也是控制领域所关心的特征。

下面，首先讨论智能系统的几种定义和某些基本特性。接着陈述一下具有共同特性的智能系统的一个简洁的工程定义。更详细地，我们从智能系统的一个非常一般的定义开始，讨论智能程度，解释控制在智能系统中的作用，并概括出几种定义。然后讨论智能系统中的自适应和自学习、自主性和必要的高效计算结构，来处理智能系统的复杂性。最后归结出智能(控制)系统的基本特征。

我们从智能系统的一般特征开始：

一个智能系统应具备在不可预测的环境下适当工作的能力，在这个环境中一个适当的反应能够增加成功的可能性，从而达到系统最终的目的。

为了能让人造智能系统适当的工作，它应能模拟生物的功能和基本的人的智能。一个智能系统能从多个方面来描述。智能程度能从智能的各个方面测得。智能至少要具有感受环境、进而做出决定来进行控制的能力。智能化程度比较高的智能系统具有识别目标和事件、描述世界模型中的知识、思考并计划未来的能力。在智能化程度更高级的形式中，智能具有感知和理解、理智地做出选择、在各种各样的环境下成功地运行以便能在复杂的、不利的环境下生存和发展的能力。通过计算能力的发展和在复杂多变的环境中怎样感知、决定并做出响应的知识的积累，我们可以观察到智能也在更新与发展。

智能系统的以上特征是非常普遍的。据上所述，很多系统都可以被认为是智能的。事实上，根据这种定义，恒温器尽管只是低水平的智能，但是也可以被认为是智能系统。然而，习惯上当一个系统具有高水平的智能时，我们才称它为智能系统。

智能系统存在许多相关的定义，下面我们提到了几种。它们提供可选择但相关的智能系统的特性，这种智能系统着重强调系统的高程度智能。

下面的定义强调这样一个事实，处理信息的系统集中在人造系统和智能机器上：

A. 机器智能是分析、组织和转换数据成知识的过程，在这里，知识被定义为结构化的信息，这种信息被用来消除无知或相对于智能机器来说某些特殊任务的不确定性。这种定义导致了增加精度而相对减少智能的原则，这种原则表示：应用机器智能到数据库能生成一系列的知识，通过分析形式进行过程建模。

其次，智能系统具有自动分配任务和在内部自主地控制执行机构的特性：

B. 许多自适应或自学习控制系统被认为是作为一种控制法则来满足明确的控制目标。这种行为代表着系统试图组织或排列自己动态行为的知识，来满足控制目标。这些知识的组织是组成智能的一个重要特征。如果系统能够自主地实现这种组织，那么智能就成为系统的一种性能，而非系统设计者的。这意味着能内部实现自组织原则的自组织控制器是智

能控制系统。

下面给出智能系统的过程特性：

C. 智能是系统的一种特性，当集中注意、联合搜索和概括等过程被应用在输入信息，从而产生输出时，这种特性就会出现。你可以很容易的推断出：一旦以上过程被定义，具有智能结构的结果规则生成并作为新的结果。只有一种标准结构将导致在恒温器中固有的一个不成熟的智能或导致成为一个可变结构的变化模型的控制器。

智能和控制的概念紧密相关，并且术语“智能控制”有着独特的、可区别的意思。一个智能系统必须定义和利用目标。控制被要求用来驱动系统达到这些目标并定义这些目标。因此，任何智能系统都是控制系统。相反地，智能必须在条件变化的情况下提供合适的系统运行过程，也必须在控制系统中具有高度的自主行为。因为控制是任何智能系统的一个重要部分，因此在工程文献中“智能控制系统”有时被用来代替“智能系统”或“智能机器”。“智能控制系统”强调智能系统中的控制方面。

下面，介绍一下智能(控制)系统的另外一些特性。根据观察，一个控制系统包括数据结构或对象(设备模型和控制目标)和处理单元或方法(控制规则)：

D. 由于组件、控制目标、加工模型和控制法则并没有完全被定义，没被定义的原因或是因为在设计时不了解，或是因为它们在不可预测地变化着。所以设计一个智能控制系统以便能自动获得高标准目标。

在具有不同智能化程度的系统中呈现出几种基本特性。你可以认为它们是智能系统的特征或是衡量智能程度的方面。下面我们讨论在智能控制系统中三种非常基本的特性。

自适应与自学习　在智能系统中适应变化多端的条件的能力是必需的。尽管自适应不一定要具备自学习能力，但一个系统要适应不可预测的各种变化，学习是最必要的。因此学习能力是高智能系统的一种重要特性。

自主性和智能　在设置和获取目标过程中自主性是智能控制系统的一个重要特性。当一个系统在一个没有外界干预的不确定的环境中能正常运行时，它就被认为是一个高自主性系统。不同系统的自主性程度是不一样的，自适应控制系统被认为比安装了控制器的控制系统具有更高自主能力，因为它比一个固定的反馈控制器更能处理不可预测的问题。尽管对低自主性来说，无智能(或“低”智能)是必然的，但是对高自主性来说，系统的智能(或“高”智能度)是很必要的。

结构和层次　为了应对复杂情况，一个智能系统必须具备一个合适的功能结构来进行有效的分析和控制决策的估计。这种结构是“稀少的”并且它应该提供一种机制来建立提取标准(决议)或者至少提供某种形式的部分规则来减少复杂性。一种研究智能机器的熵方法能加强这种有效的计算结构。能够适应的层次(或许是大致的、局部的或是组合的层次)，可以作为一种主要的工具来处理复杂性。这里的“层次”术语是指功能性层次，或者是指时空的范围和决议，而且它并不意味着是一种层次硬件。这里面的某些结构可能是硬件的。为了应付多变的环境，自学习能力是必要的，因此这种结构应能适应重要的、不可预料的变化。

鉴于以上所述，具有其他任何系统都存在的基本特性的智能系统(高智能控制系统或机器)的一个工作特征是：

一个智能系统必须对重要的、不可预料的变化具有很高的适应性，而且自学习也是必

要的。在应对变化因素时它必须呈现出高度自主性。它必须能够处理非常复杂的问题，而且这将导致某些稀少的、例如层次这样的功能机构。

第 19 课　PLC 简介

PLC(即可编程逻辑控制器)是机械控制中为替代必要的继电器时序电路而发明的一种设备。PLC 工作时通过查询输入端并根据其状态打开或关闭输出。用户通常用软件或编程器输入程序，从而获得期望的结果。

很多实际应用都采用 PLC。工业生产中应用 PLC 的可能性很高。如果你正在进行机械制造、产品包装、材料处理、自动化装配及无数其他工业生产，你可能已经用到了 PLC。如果没有用到，那就是在浪费金钱和时间。几乎所有需要电气控制的地方都需要 PLC。

例如，假定在开关闭合时我们需要一个线圈接通 5 秒，然后不管开关接通多长时间都将线圈断开。我们可以通过一个简单的外部定时器来实现。但是假如该过程有十个开关和线圈呢？我们就需要十个外部定时器。如果这个过程需要分别记录每个开关开启的次数呢？我们又需要很多外部计数器。

由此可见，系统越大，我们就越需要 PLC。我们可以简单地用 PLC 编程来对输入信号进行计数，并在规定的时间接通线圈。

我们考察一下哪些是 PLC 中最常用的 20 条指令。保守地估计一下，如果真正地掌握了这些指令，就能解决 80%以上现存的应用问题。

是的，80%以上！当然，我们要学习的指令比这些更多，以帮助你解决几乎所有潜在的 PLC 应用问题。

PLC 主要由中央处理器(CPU)、存储器和输入、输出电路构成，如图 19.1 所示。我们可以将 PLC 看成是一个装满了成百上千个独立的继电器、计数器、定时器以及数据存储器的盒子。这些计数器、定时器等是不是真的存在呢？不，它们都是模拟的，物理上并不存在，但可以将它们看成是软计数器、软定时器等。这些内部继电器是用寄存器中的位单元模拟出来的。

各个部分是如何工作的呢？

输入继电器(触点)这些继电器连接外部电路。它们是实际存在的，并接收来自开关、传感器等的信号，通常是晶体管而非继电器。

内部通用继电器(触点)它们不从外部设备接收信号，也非物理上存在的。它们是模拟的继电器，用以消除 PLC 的外部继电器。此外还有一些特殊继电器，专门执行一项任务。其中一些是常开的，一些是常闭的。有一些仅在电源上电时导通一次，通常用来初始化存储的数据。

计数器 它们也非物理上存在的，而是模拟的计数器，可通过编程来对脉冲进行计数。通常它们可进行加计数、减计数或同时进行加减计数。因为它们是用软件模拟的，计数速度就有限。一些制造商提供了基于硬件的高速计数器。这样的计数器可以认为是物理上存在的。这些计数器多数情况下可以进行加计数、减计数或同时进行加减计数。

定时器 它们也非物理上存在的，分为多种类型和定时单位。最常用的一种类型是延时导通型。其他类型还有延时断开型、记忆和非记忆型。定时单位的范围是 1ms 到 1s。

输出继电器(线圈) 该部分连接到外围电路。它们是物理上存在的，并给线圈、灯等发送开关信号。输出继电器可以是晶体管、继电器或可控硅，取决于选择的型号。

数据存储器 它们通常是用来存储数据的寄存器，一般作为运算或数据处理的暂存器。在 PLC 断电时通常还可用来存储数据。再次接通电源后，其内容与断电前相同，非常方便且必要。

PLC 是通过连续扫描一个程序来工作的。我们可以认为扫描周期是由 3 个主要阶段组成的，如图 19.2 所示。当然有多于三个阶段的情况，但我们可关注重要的环节，忽略其他环节。其他阶段通常正在检查系统及更新内部计数器和定时器的当前值。

第一步——检查输入状态——首先 PLC 检查每一个输入是否接通。换句话说就是，与第一个输入端连接的传感器接通了吗？第二个输入呢？第三个输入呢？…PLC 将这些数据记录到存储器中，以便在下一阶段使用。

第二步——执行程序——然后 PLC 一次一条指令地执行程序。你的程序可能要求第一个输入接通时，就接通第一个输出。因为在上一步已经知道输入端的开关状态，根据上一步中第一个输入端的状态，就可以确定是否应接通第一个输出。PLC 将执行结果存储起来，以供下一步使用。

第三步——更新输出状态——最后 PLC 更新输出状态。PLC 根据第一步中接通的输入和第二步中程序执行的结果更新输出状态。由于第一个输入接通了，程序要求在该条件满足时就接通第一个输出，根据第二步的情况，PLC 就接通第一个输出。

PLC 在执行完第三步后就返回到第一步，并反复循环。一次扫描时间定义为执行上面的三步所花的时间。因此，一个实际的系统应根据要求去执行特定的操作。

第 20 课　带有只读存储器的单片机集成电路

单片机集成电路包含一个处理器内核，它至少通过一种数据处理或存储设备来交换数据。集成电路包含一个只读掩模程序存储器，其中像测试程序一样的通用程序能被单片机执行。这种通用程序具有将数据写到数据处理和/或存储设备的基本功能。写入功能用于装载程序。因为装载程序并非永久地存储在只读存储器中，所以可对单片机进行测试，而与应用程序无关，并保持系统中能用的存储器元件为标准类型。

准确地说，这项发明涉及单片机集成电路。单片机通常是包含一台“计算机”的全部或大部分元件的大规模集成电路，其功能不是预先确定的，而是取决于它执行的程序。

一台单片机必然包含一个含有命令时序发生器(即根据程序的指令分配各种控制信号到其他元件的装置)的处理器内核、一个算术逻辑单元(用来处理数据)和寄存器(即特殊的存储单元)。

然而，“计算机”的其他元件对单片机而言或是内部的，或是外部的。换言之，其他元件就集成到单片机或辅助电路中。

“计算机”的这些其他元件是数据处理或存储装置，例如包含待执行程序的只读或随机存储器、时钟和接口(串行或并行)。

基于单片机的系统通常包含一个含有单片机的芯片和许多含有外部数据处理和/或存储器件的芯片，这些芯片没有集成在单片机中。例如，这种基于单片机的系统包含一个或

多个印刷电路板，上面安装着单片机和其他元件。

决定单片机系统所有操作的是应用程序，即由单片机执行的程序。因此，每个应用程序都是针对特定的应用的。

在多数现实应用中，由于应用程序太大，单片机无法存储，因此就存储在单片机的外部存储器中。这种只能读出而不能写入的程序存储器通常就是可编程只读存储器。

应用程序在写入到存储器中后就开始执行，以便由单片机来执行。单片机系统有可能不会像预期的那样工作。

在最不顺的情况下，这只是系统的小故障，单片机仍然能够通过串行口或并行口与测试设备对话。测试设备就能够确定问题的性质，并准确地指出校正的类型(软件和/或硬件)，将其应用到系统上，以便正确操作。

遗憾的是，基于单片机系统的多数故障导致整个系统死锁，阻止了任何与测试设备的对话。这样就不能确定错误类型是硬件错误(单片机本身、外部只读存储器、外围设备、总线等)还是软件错误(应用程序的错误)。在系统死锁的情况下，采用的故障诊断方法通常以使用精密测试设备为基础，因而要求将探测仪连接到处于测试中的单片机系统的各种集成电路的管脚上。

采用测试设备对基于单片机的系统进行故障诊断，其相关问题还有很多。由于电路体积小，布线密集，而测试设备中使用的探针容易损坏，用起来很麻烦，就可能与电路接触不好。

此外，由于成本高，这些测试设备不是批量生产。结果，出故障的单片机系统就不能及时修复，不管它们此时安装在何处，首先必须送到有测试设备的地方。单片机系统的这种故障诊断方式既费时又麻烦，成本也高。

在改变系统中单片机执行的应用程序时，为了避免直接在单片机系统上进行操作，常规的做法是用可下载的只读存储器来存储应用程序，即写入到单片机掩模 ROM 中的装载程序。单片机的掩模 ROM 集成到单片机中，并在生产单片机时一次性编程写入。

为了改变应用程序，单片机通过运行装载程序而重置。这个装载程序能通过合适的传输线与连接到单片机的工作站通信，而工作站提供写入到单片机的新的应用程序。装载程序接收新应用程序并存储到单片机的外部 ROM 中。

尽管这种方法避免了对单片机系统的直接操作(这需要从系统取出包含应用程序的可编程只读存储器，并用合适的编程设备将新的应用程序写进存储器，然后换到系统中)，但是它仍然有一个较大的缺点，即在生产中对单片机的特殊处理。

由于编程参数(编程电压，外加电压的持续时间等)随着采用的技术而变化，每一种可编程存储器与对应的装载程序密切相关。装载程序一次性写进单片机内部的掩模存储器中，存储器因而就限制为装载程序要写入的存储器类型。换而言之，单片机不是标准器件，这就增加了生产成本。

这一发明就是为了克服先前技术的各种缺点。准确地说，该发明的目的就是要提供一种单片机产品，以便快速、简单、可靠、低成本地验证单片机系统的操作。

这项发明的另一个目的是提供一种单片机芯片，在系统出现故障时，可以借助于单片机准确地定位系统中失效的器件。

这项发明的更高目的是提供一种单片机芯片，在系统中能使用的存储器件为标准类型

时，不用直接对单片机系统进行操作就可改变应用程序。

第 21 课　CAD 和 CAM

术语 CAD/CAM 是计算机辅助设计(CAD) 和计算机辅助制造的(CAM) 的缩写。那么，什么是一个通用的 CAD 系统呢？

在开发通用 CAD 系统时要考虑该系统应具有尽可能广的应用范围，有以下几个方面要详细考虑：

(1) 机械工程设计；

(2) 建筑设计；

(3) 结构工程设计；

(4) 电子电路设计；

(5) 动画和图形设计。

在各个领域，不论其应用程度如何，包括作图在内都应该具有 4 个基本过程，即：

(1) 纯分析——标准设计和分析过程；

(2) 纯绘图——用手工画线、圆弧等绘出的图或画；

(3) 分析作图——直接分析的方法产生一副图或图的一部分，例如作凸轮轮廓图；

(4) 绘图分析——对用图形方式描述的一个项目进行特性评估，如通过对建筑师规划图的分析，得出该项目的工程量表。

对于能支持纯分析的系统，必须提供运行无限长分析程序以及存储和快速检索大量数据的工具。

人们看重的一点是，用户能够通过直接和图形方式与分析程序通信。提供给通用绘图设计系统的作图工具应该充足。然而由于实际的制图技术范围太广，作图系统只能尽可能多地将实用工具包含进去，而将其他更专门的技术留给应用程序员去开发。

对于由分析产生的作图项目和绘图分析而言，由作图系统所产生的数据和分析程序之间必须有一个简单高效的联系。另外，图形数据可用能被分析程序识别但不对作图系统产生影响的方法进行注释。

对大多数实际应用来讲，应考虑把通用作图系统合并到大型专用系统中。作图系统因而应该尽可能简单而高效地运行，这样把作图系统合并到应用系统就不用花很多精力。

现在说明通用 CAD 系统包含的工具，这些工具的作用在于允许用户将图形信息输入计算机并归档。原始数据的输入通过将草图数字化而完成。该系统也允许用户存取、加工、处理并以硬拷贝形式输出这些数据，或者重新归档为永久性存储文件。

使用 CAD 的原因有很多，最有效的动力就是竞争。为了赢得业务，公司使用 CAD 可以创造出更好的设计，并且在设计速度上比竞争对手更快，在成本上花费更少。通过使用 CAD，生产率得到了很大提高，使用户能够很容易地画多边形、椭圆、多条平行线和多条平行的曲线。在绘制对称部分时、复制、旋转、镜象这些工具使用起来也是很方便的。很多飞机舱口的样式就是用 CAD 程序设计的。用各种不同的颜色填充空白的区域是艺术和表达的需要。CAD 总是提供许多不同类型的字体。能够将不同的图形文件格式和扫描材料(照片)导入 CAD 也是一大优点，特别是可以对图像进行加工、润饰和加入动画效果。

CAD 系统另外一个优点是能够存储在绘图中经常用到的实体。常用零件库可以另外购买或者由绘图员自己创建。在绘图中反复使用的一个典型的项目可以在数秒内检索并确定它的位置，也可定位在任一角度，以满足特定的要求。

使用 CAD 产品，可以通过插入现有的零件图到装配图中，然后按照要求把他们放在合适的位置来绘制装配图。

不同零部件之间的间距能够在图中直接测量。如果需要，可以使用装配图设计出额外的零部件作为参考。

CAD 非常适合文件的快速归档。以前，工程师和绘图员们浪费大约 30%的时间去寻找图纸和其他文档。用 CAD 产品可以快速而简便地编辑图样，对以前的东西进行修改，更新零件明细表。

当你用纸绘图而客户希望修改图样的时候，你就得全部重画。使用 CAD，你可以马上进行修改，并在几分钟之内打印出新图，或者通过 E-mail 和互联网立即传送到世界的各个地方。在纸上绘制复杂的几何图形时，经常要进行很多测量并且需要确定参考点。在 CAD 中，这是一个轻而易举的事情，修改也更容易了。许多 CAD 程序包含“宏”或者允许用户定制的附加程序语言。

定制你的 CAD 系统来使它适合你的特定要求，并用它实现你的天才创意，从而能使你的 CAD 系统区别于你的竞争对手。CAD 能够使企业完成更出色的设计，而用手工的方式几乎是不可能，同时排除了概念设计阶段的不确定选项。

许多 CAD 系统允许快速生成提出的设计模型作为一个线框模型。在 CAD 里创建的实体造型可以输入到一个有限元分析(FEA)程序内，以检验设计方案能否承受预期的负荷。

CAD 总是尽可能地和 CAM(计算机辅助制造)联系在一起。

CAD/CAM 系统能够为计算机化的电机控制器产生计算机指令。例如车床、磨床、加工中心、旋转冲头、焊接设备和自动化装置等。

CAM 是从数控机床技术中发展来的。早期的数控机床用于伺服驱动装置和电机的机载电子控制系统，编程要用穿孔纸带，然后及时地变成等效的 ASCII 码文本数据控制流，输入到文本编辑器。

每个设备制造商都开发自己的控制码方案，通常是一组用于表示机械运动的秘密字符和表示速度、深度等和位置坐标的数值。

数控机床包括一个带有屏幕和键盘的计算机。他们使用“常规”的控制语言。现代的 CAD/CAM 系统能够自动的从三维模型中产生刀具路径，并且能够在屏幕上模拟切削动作。大部分的 CAD/CAM 系统是模块化的，这就意味着你可以只购买你需要的模块并把他们集成为一个统一的系统。

CIM(计算机集成制造)是指基于计算机化信息的制造业各方面的完全集成。

CIM 是 CAD 产生的零件数据在 CAM 环境中的应用。换句话说，就是将计算机化的零件加工的几何形状用于数控编程。这个发展阶段可以称作小规模集成。

CIM 开发的最高级模式是创建一个数据库，其中包含了工厂用于生产零件的柔性制造系统需要的所有信息。在这种模式下，任何需要的人都可以检索和使用。柔性制造是指能够快速、经济地生产任意小批量或大批量的零件，从而减少加工费用、工作量并降低高昂的库存费用。

计算机集成制造中的主要信息流程已经由 Helberg 清楚地概括出来。CAD 生产产品模型以及产品描述数据，这些数据由 CAPP(计算机辅助工艺规划)转换成工艺流程和 CAM 系统的控制程序。PPC 系统(生产计划和控制系统)产生并管理所有在 CAM 中用于控制的操作数据。CAQ(计算机辅助质量保证)校正制造过程中的短期偏差，但从长远看则影响产品的开发和关于质量保证的方法。

Helberg 的信息流程没有包括系统之间必要的或者期望的更进一步的信息连接。例如在设计和确定工艺流程时，伴随着计算所进行的 CAD/CAPP 和 PPC 之间的连接，或者从制造到计划的反馈。此外，至少在加工单件零件的情况下，诸如设计和工艺规划这样的过程可以认为是订单交付周期的一部分。因此，它们可以像实际加工和装配过程一样由 PPC 系统规划和控制。在这种情况下，相应的反馈就变得非常必要。

CIM 的理论家们认为，系统集成化和合理化不是一个简单的技术方法问题。为了把分散的不兼容系统集成起来，不能只是简单地投入大量的经费和设备，而必须改变传统的工艺过程。但只要想改变工艺过程，就会遇到阻力。公司越大，网络就越独立，改变生产策略和工艺过程就越困难。正如图 21.1 所示，成功的系统集成条件是在分布式环境的全局上，沿功能轴和支持轴(硬件和软件)扩展。

因为使用 CIM 带来的切实利益和潜在的利益是长期，常用的折扣现金收支流和投资回报率的评价方法不能经常有效地评估一个安装了 CIM 的柔性制造系统。相反，必须用战略性优势和潜在的利益来估量对 CIM 投资的期望。

第 22 课　电机起动和制动系统

电机起动系统

电机尤其是大电机的起动对电动机构的运行效率起着非常重要的作用。可以用几种不同的系统起动电机。使用的电机起动装置位于电源和电机之间。在起动过程中，电机从电源获得一个比正常运行时大得多的电流。通常用电机起动装置将起动电流减小到一个电力系统可以控制的水平。

1. 全压起动

电机起动的方法之一叫全压起动。这种方法投资最昂贵但安装最简单。由于额定电压从起动初始就施加到电机上，所以会产生最大起动转矩和最小加速时间。然而，电力系统必须能控制由电机汲取的起动电流。

电机起动的原理如图 22.1 所示。在这个电机控制回路中，三相电机由一个启闭按钮来控制。当按下常开起动按钮时，电流流过继电器线圈 M，使得常开触点闭合。当这些常开触点闭合后，其中的线触点就将全压加到电机上。松开起动按钮后，由于有吸持式触点，继电器线圈仍保持通电。这个吸持式触点提供了一条电流路径，从 L1 流过常闭停止按钮、吸持式触点、线圈 M、热过载继电器，最后回到 L2。当按下停止按钮时，电路断开，线圈失电。

2. 主电阻起动

电机起动的另一种方法叫主电阻起动。这种方法将大电阻串联在线路中，以减小电机

的起动电流。通常，连接在线路中的电阻逐级减小，直到额定电压全部加到电机上。这样，起动转矩将随着流过的电流幅值而减小，而起动电流又将随着线路中串联的电阻值而减小。

图 22.2 所示为用于控制三相电机的主电阻起动方法。当按下起动按钮，线圈 S 和 TR 通电，触点 S 闭合，将电源电压通过主电阻器分压后施加到电机上，这些电阻器减小了起动电流值。一旦延时继电器 TR 的延时周期到了，触点 TR 就会闭合。运行触点 R 就会闭合，将全压施加到电机上。

3. 主电抗起动

另一种电机起动方法与主电阻起动相似，叫主电抗起动。这种方法是用电抗器(线圈)替代电阻器，因为在交流电时它们消耗较少的能量。这种方法通常更适用于额定电压超过 600 伏的大电机。

4. 自耦变压器起动

自耦变压器起动是用于电机起动的另一种方法。这种方法使用一个或多个自耦变压器来控制加到电机上的电压。接入的自耦变压器通常用于提供一个起动电流控制范围。当电机加速到它的额定转速附近时，从线路中去掉自耦变压器绕组。这种方法的主要缺点是自耦变压器的花费大。

一个自耦变压器回路如图 22.3 所示。这是一种使用了 3 个自耦变压器和 4 个继电器的昂贵的控制类型。当按下起动按钮，电流流过线圈 1S、2S 和 TR，1S 和 2S 触点将闭合。电压经过自耦变压器绕组分压后加到三相电机上。一个常闭触点和一个常开触点都由延时继电器 TR 控制。当整定时间周期到了，常闭 TR 触点就会打开，常开 TR 触点闭合。线圈 R 充电，使得常开 R 触点闭合给电机提供全压。常闭 R 触点与线圈 1S、2S 和 TR 串联，当线圈 R 充电时断开线路。当按下停止按钮，流过线圈 R 的电流中断，这样就断开了接到电机的电源线。

注意　图 22.3 中的自耦变压器使用的是 65%抽头，另外还可选用 50%、80%和 100%的抽头以保证在减小电机起动电流时更大的灵活性。

5. Y-△(星形-三角形)起动

使用星形-三角形起动可能是起动三相电机的更为经济的方法。因为在一个星形结构中，线电流等于相电流除以 1.73($\sqrt{3}$)，所以使用星形结构比使用三角形结构起动电流更小。如图 22.4 所示，这种方法在起动时用一个开关使电机定子绕组以星形结构排布，在运转时又以三角形结构排布。用这种方法减小了起动电流。尽管起动转矩减小了，但由于电机以三角形结构连接时每个绕组上承受的是全电压，所以运行转矩仍然较大。

按下图 22.4 中的起动按钮，线圈 S 通电，则常开 S 触点闭合。这个动作将电机绕组连成星形结构，并且也激活了延时继电器 TR 和线圈 1M。从而常开 1M 触点闭合给星形电机绕组供电。当延时周期到期时，TR 触点改变状态。线圈 S 断电，线圈 2M 通电，则保持电机绕组为星形连接的 S 触点打开。2M 触点闭合使得电机绕组以三角形结构连接。电机以定子绕组三角形连接连续运转。

6. 直流起动系统

由于直流电机在不旋转时没有反电动势，它的起动电流非常大，因此必须使用某种控制系统，例如用一个串联电阻来减小初始的起动电流。可以手动或自动减小电阻，直到全电压加到电机上。直流电机常用的 4 种类型控制系统是：①电流限制，②定时，③反电动势，④可变电压。限电流这种方法允许将起动电流减小到一个限定水平然后接入下一级电阻。定时这种方法使电机在一定时间间隔内增速，与电枢电流值或电机转速无关。反电势方法采集由电机电枢产生的反电势值从而来减少串联电阻。使用这种方法很有效，因为反电势与直流电机的转速和电枢电流都成正比。可变电压方法使用一个可变直流电源，开始给电机提供一个递减的电压然后逐渐增大电压。使用这种方法无需串联电阻。

冲击制动

关断电机时，它的轴还会持续旋转几周。这种持续旋转在许多应用场合是不希望有的。冲击制动是一种无论何时切断电源都能将电机快速停转的方法。带有励磁电枢的电动机利用一个与电枢相连的电阻去制动。当电源被切断时，电阻连接在电枢上，这使得电枢工作在带有负荷性质的发电机状态，使得电机立即减速。这种冲击制动法如图 22.5 所示。

交流感应电机可以通过在电机绕组上连接直流电压来快速减速。这个直流电压建立一个恒定的磁场使得转子快速减慢。一个单相交流感应电机的冲击制动回路如图 22.6 所示。

第 23 课　直流电动机速度控制

调节系统

调节系统是一类通常能提供稳定输出功率的系统。

例如，电机速度调节器要能在负载转矩变化时仍能保持电机转速为恒定值。即使负载转矩为零，电机也必须提供足够的转矩来克服轴承的粘滞摩擦影响。其他类型的调节器也提供输出功率，温度调节器必须保持炉内的温度恒定，也就是说，即使炉内的热量散失也必须保持炉温不变。一个电压调节器必须也保持负载电流值变化时输出电压值恒定。对于任何一个提供一个输出，例如速度、温度、电压等的系统，在稳态下必定存在一个误差信号。

电气制动

在许多速度控制系统中，例如轧钢机、矿坑卷扬机等这些负载要求频繁地停顿和反向运动的系统。随着减速要求，速度减小的比率取决于存储的能量和所使用的制动系统。一个小型速度控制系统(例如所知的伺服积分器)可以采用机械制动，但这对大型速度控制器并不可行，因为散热很难并且很昂贵。

可行的各种电气制动方法有：

(1) 回馈制动。
(2) 涡流制动。
(3) 能耗制动。
(4) 反接(向)制动。

回馈制动虽然并不一定是最经济的方式，但却是最好的方式。负载中存储的能量通过工作电机(暂时以发电机模式运行)被转化成电能并被返回到电源系统中。这样电源就充当了一个收容不想要的能量的角色。假如电源系统具有足够的容量，在短时回馈过程中最终引起的端电压升高会很少。在直流电机速度控制渥特-勒奥那多法中，回馈制动是固有的，但可控硅传动装置必须被排布的可以反馈。如果轴转速快于旋转磁场的速度，感应电机传动装置可以反馈。由晶闸管换流器而来的廉价变频电源的出现在变速装置感应电机应用中引起了巨大的变化。

涡流制动可用于任何机器，只要在轴上安装一个铜条或铝盘并在磁场中旋转它即可。在大型系统中，散热问题是很重要的，因为如果长时间制动，轴、轴承和电机的温度就会升高。

在能耗制动中，存储的能量消耗在回路电阻器上。用在小型直流电机上时，电枢供电被断开，接入一个电阻器(通常是一个继电器、接触器或晶闸管)。保持磁场电压，施加制动降到最低速。感应电机要求稍微复杂一点的排布，定子绕组被从交流电源上断开，接到直流电源上。产生的电能继而消耗在转子回路中。能耗制动应用在许多大型交流升降系统中，制动的职责是反向和延长。

任何电机都可以通过突然反接电源以提供反向的旋转方向(反接制动)来停机。在可控情况下，这种制动方法对所有传动装置都是适用的。它主要的缺点就是当制动等于负载存储的能量时，电能被机器消耗了。这在大型装置中就大大增加了运行成本。

直流电机速度控制

所有直流电机速度控制的基本关系都可由下式得出：

$$E \propto \Phi\omega \tag{23-1}$$

$$U = E + I_a R_a \tag{23-2}$$

各项就是它们通常所指的含义。如果 I_aR_a 很小，等式近似为 $U \propto \Phi\omega$ 或 $\omega \propto U/\Phi$。这样，控制电枢电压和磁通就可影响电机转速。要将转速降为零，或者 U=0 或者 Φ=∞。后者是不可能的，因此只可通过电枢电压的变化来降低转速。要将转速增加到较高值，可以增大 U 或减小 Φ。后者是最可行的方法，就是我们通常所知的弱磁场。在要求速度调解范围宽的场合可综合使用这两种方法。

使用晶闸管的单相速度控制系统

一个单相晶闸管逆变器系统如图 23.1 所示。读者应该先忽略整流器 BR2 和它的相关电路(包括交流回路中的电阻器 R)，因为这部分只有在具有保护功能时才需要，将在下一节介绍。

因为该电路是一个单相转换器，只能在一个旋转方向控制电机轴(系统的输出)的速度。而且，回馈制动不能用于电机；在这种系统类型中，电机电枢可以通过电气制动静止(例如，当晶闸管门极脉冲反相时，电阻可通过一个继电器或其他装置连接到电枢上)。

整流器 BR1 给并联励磁绕组提供一个稳定电压，产生稳定的磁通。电枢电流由一个晶闸管控制，该晶闸管又由加在它门极上的脉冲控制。脉冲正相时(减小起动延时角)电枢转速增加，门极脉冲反相时电枢转速减小。

速度参考信号可从人工操作的电位器(如图 23.1 右侧所示)上获得，反馈信号或输出转速信号可从连接在电枢上的电阻器链 R_1R_2 上获得。(严格地讲，图 23.1 系统中反馈信号只

有当电枢电阻压降 I_aR_a 很小时，才与轴转速成正比的电枢电压成正比。用于补偿 I_aR_a 压降的方法将在阅读材料中讨论。)因为电枢电压是从一个晶闸管上获得的，该电压包括一系列由电容器 C 滤波的脉冲。速度参考信号与电枢电压信号极性相反，以确保施加的都是负反馈。

直流电机装置的一个特征就是需要供电的负载是电阻、电导的混合，并且在图 23.1 中反电动势二极管 D 确保当晶闸管阳极电势低于前面叙述的电枢连接方式的上限时，晶闸管电流应换向为零。在所示拖动系统中，当晶闸管处于关断状态时，其阳极电势等于电机反电势。只有在瞬时电源电压大于反向电势的间隔时它才会导通。图 23.2 所示的检测表明电机运行时晶闸管上峰值反向电压大于峰值正向电压。如图所示，在晶闸管上串联一个二极管，电路的反向关断能力就会增强，所以允许使用低压晶闸管。

图 23.2 所示的波形是理想波形，因为忽略了电枢电感、换向器纹波等因素的影响。典型的电枢电压波形如图 23.3 所示。在该波形中，晶闸管在 A 点触发，一直到 B 点电源电压低于电枢反电势时导通。电枢电感的作用使晶闸管保持到 C 点飞轮二极管使电枢电压反向之前导通。当电感能量消失(D 点)，电枢电流为零，电压恢复到它的正常水平，这个暂态过程最后稳定在 E 点。点 E、F 之前的纹波是由换向器引起的纹波。

第 24 课　交流电机的频率控制

调频的概念

让我们先来复习一下线换流和强迫换流的概念，因为它们用于获得应用在交流鼠笼型感应电动机的可调频率。图 24.1 说明了控制器需要做的工作：从固定线电压和固定线频率中产生一个可调电压和可调频率。让我们首先确定把什么放入框图中。这个使用 6 个晶闸管的电路并不能工作。它可以给电机产生一个可调电压，但是线频率会直接通过。因此，我们需要一种方法像产生一个可调电压一样产生一个可调频率。最简单的方法就是通过“直流环”。该直流环又由好几个元件控制来产生可调频率。在有些情况下，直流环也由可调电压控制。为了构成直流环，进线的交流电压必须先通过某种方式整流之后再逆变给交流电机供电。

图 24.2 所示为一个具有直流环的常用的频率控制器。输入端使用 6 个半导体元件，提供直流电，输出端使用 6 个半导体元件提供可调频率。在每个框中应选用那种类型的半导体呢？因为交流进线总是连接到第一个框中，故输入装置可以是线换向，因此可以使用二极管、晶闸管、门电路可关断晶闸管、三极管或双向晶闸管。门电路可关断晶闸管很昂贵，三极管和双向晶闸管的电流和电压容量又有限。因此，输入功率元件应是二极管或晶闸管或它们的组合。

另外，图 24.2 中的输出框装置必须使用强迫换向，因为自然换向或线换向装置不能关断功率半导体。这就意味着必须使用晶闸管、三极管或门电路可关断晶闸管。也可使用双向晶闸管，但容量受到限制。

让我们从输入框中的二极管入手。使用二极管，就不能产生可调直流环电压。因此，可调频率和可调电压必须在输出级产生。实际当中也就是这样做的。最后得到的系统称作脉宽调节器。

如果输入框采用晶闸管而不是二极管，就可以通过控制晶闸管来提供可变的直流环节

电压了。输出级就只需输出从直流环中产生可调频率并且把可调电压连同可调频率一起传送给交流电机。输出级因此比脉宽调节系统的简单些，但输入级必定更复杂。然而，这种方法的两种排布也普遍应用于频率控制器。一种是所谓的电压型逆变器，另一种就是所谓的电流型逆变器。

表 24-1 是这 3 类最常用频率控制器使用的功率元件一览表。

专业术语

让我们先来复习一些用来描述固态频率控制器的术语。它们像常用术语一样有严格的专业定义。这些专业定义由诸如国际电气公司、全国电气制造商协会和电气与电子工程师协会这样一些组织来规定：

(1) 转换器：一种包括一个或多个阀门装置(例如功率半导体)的用于电能转换的工作元件。

(2) 自整流转换器：一种换向电压由转换器内部元件提供的转换器。

(3) 整流器：一种将交流转换成直流的转换器。

(4) 逆变器：一种将直流转换成交流的转换器。

(5) 间接交流转换器：一种包括一个整流器和一个逆变器直流环的转换器。

如果我们看图 24.2，将上面所有的定义应用在固态频率控制器的一种或另一种形式中，那么定义 5 就包含了完整的系统。然而，在美国通常称图 24.2 所示的结构为“逆变器”：脉宽调节逆变器、可调电压型逆变器或电流型逆变器(也称作可调电流型逆变器)。

在本章，后面我们使用“可调频率控制器”和可交(互)换的“逆变器”这两个术语。当然，在任何没有正确使用专业术语时我们可以不加区分。

脉宽调节器、电压型逆变器和电流型逆变器

如图 24.2 所示，这 3 种最常用的调频控制器都包括 3 个基本部分。输入部分将输入的交流电转化成直流，中间部分或直流环部分将直流电压滤波，输出部分将直流电压转换成所需频率的交流电。

这三种类型控制器的不同之处在于(a)获取可调电压的方法和(b)用于产生可调频率的技术。

脉宽调节器

脉宽调节器在输入级使用二极管来提供一个具有恒定电压的直流母线。输出或逆变级产生一系列恒定脉冲，它的脉宽和脉冲数量随着需要的输出频率和电压而变。输出级提供并控制可调频率和可调电压这两个参数。

电压型逆变器

可调电压型逆变器在输入级使用晶闸管，在直流环中获取可调电压。输出级用晶闸管、三极管或门电路可关断晶闸管控制直流电压来获取宽度和时序与所需频率成正比的方波电压。第一级获得电压控制，第二级获得频率控制。

电流型逆变器

电流型逆变器与电压型逆变器相似，区别只在于通过它的控制可提供一系列电流输出

方波。

4. 比较脉宽调节器、电压型逆变器和电流型逆变器

图 24.3 所示为这 3 种类型的调频控制器电路以及最终的理论输出电压和电流波形。这 3 种基本系统有许多不同之处，例如用脉宽调节器调节正弦波、交流变换技术和提供一种负载换向的输出电路。这些超出了本书的讨论范围，可在参考书中查阅。

第 25 课　基于 MATLAB 的简单连续系统建模

什么是 MATLAB

MATLAB 是一种用于技术计算的高级语言。它集计算、可视化和编程于一体，在这个便于使用的环境中，问题和解决方案都可以用熟悉的数学符号来表示。MATLAB 的典型用途包括：

- 数学计算
- 算法开发
- 数据采集
- 建模、仿真
- 数据分析、开发和可视化
- 科技工程制图
- 发展应用，包括图形用户界面的建立

MATLAB 是一个交互式系统，它的基本数据元素是一个不要求维数的数组。这样可以解决许多技术计算问题，特别是那些带有矩阵和矢量公式的问题，用户用很少的时间就可以用文本语言如 C 或 Fortran 编一段程序来解决。

MATLAB 这个词表示矩阵实验室。起初 MATLAB 是用来解决 LINPACK 和 EISPACK 项目开发的矩阵运算问题的。现在，MATLAB 合并了 LAPACK 和 BLAS 库，引入状态变量于软件中用于矩阵运算。

MATLAB 经过多年的发展，融入了许多用户的经验成果。在大学，它已成为一个在数学、工程和科学领域的导论课和专业课的标准教学工具。在工业领域，MATLAB 成为高生产力的研究、开发和分析的首选工具。

MATLAB 拥有称作工具箱的专业应用领域的解答方案。对大多数 MATLAB 用户，十分重要的一点是，工具箱可以使你学习和应用专业技术。工具箱是将 MATLAB 环境扩展到解决特定领域问题的 MATLAB 函数(M 文件)的综合运用。目前工具箱已涉及的领域包括信号处理控制系统、神经网络、模糊控制、小波、仿真等。

MATLAB 主要包括 5 部分：

MATLAB 环境。这是一个可以帮助你使用 MATLAB 函数和文件的工具，是图形用户界面。它包括 MATLAB 桌面和命令窗口、命令历史、编辑器和调试器、帮助浏览器、工作空间、文件和查询路径。

MATLAB 数学函数库。这是一个涵盖了像求和、正弦、余弦这样一些基本函数、复杂算法和像矩阵求逆、矩阵特征值和贝塞尔函数、快速傅里叶变换这样一些复杂函数的计

算运算法则大集合。

MATLAB 语言。这是一种高级矩阵语言，具有可以控制流状态、函数、数据结构、输入输出和面向对象编程的特征。它允许快速创建小程序，也可以创建大的复杂的应用程序。

图形处理。MATLAB 可方便地将矢量和矩阵用图形来显示，也可注释和打印图形。它包括一些高级函数，这些高级函数可用于二维和三维数据可视化、图像处理、动画和图形再现。它也包括一些低级函数，可使用户定制图形界面和在你的 MATLAB 应用软件上创建完整的图形用户界面。

MATLAB 应用程序界面。这是一个允许你将 C 语言和 Fortran 语言与 MATLAB 结合的库。它可以从 MATLAB 动态链接库中调用程序、将 MATLAB 作为一个计算引擎、读或写 MAT 文件。

对一个简单连续系统进行建模。

搭建该微分方程的模型

$$x'(t) = -2x(t) + u(t) \tag{25-1}$$

其中 $u(t)$ 是幅值为 1、角速度为 1 弧度/秒的方波。积分器模块对它的输入信号 x'积分产生 x。该模型还需要一个增益模块和求和模块。要产生方波可使用信号发生器模块并选择方波形式改变其默认单位为弧度/秒。同时，用一个示波器模块观测输出。连接模块并定义增益系数。

在该模型中，要倒转增益模块的方向必须先选中该模块，然后使用格式菜单中的翻转模块命令。要连接从积分器模块到增益模块的分支连线，须在画线时按住 **Ctrl** 键。现在你就可以连接上所有的模块了。如图 25.1 所示。

在该模型中一个重要的概念就是包括一个由求和模块、积分器模块和增益模块构成的环。在该方程中，x 既是积分器模块的输出，也是基于 x 计算 x'的模块输入。这种关系是通过使用一个环来实现的。

示波器在每一个时间步显示 x。仿真持续 10 秒的输出波形如图 25.2 所示。

在这个例子中，建模的方程也可以用一个传递函数来表示。模型使用传递函数模块，u 为输入 x 为输出。因此，该模块可实现 x/u。如果用 sx 替代上式中的 x'，就可得到

$$sx = -2x + u \tag{25-2}$$

可求得

$$x = u/(s+2) \tag{25-3}$$

或

$$x/u = 1/(s+2) \tag{25-4}$$

传递函数模块可以用参数来定义分子和分母系数。在这个例子中，分子是 1，分母是 $s+2$，定义各项为衰减系数为 s 的矢量。在这个例子中，分子是 [1](或 1)，分母是 [1 2]。该模型就变得非常简单，如图 25.3 所示。

仿真结果与之前模型的仿真结果完全相同。