CENTURY 21

高等学校教材
科技英语系列教程

Technology

邢小军 吴梅 编

自动化科技英语

English of Science and Technology for Automation

西北工业大学出版社

高等学校教材

自动化科技英语

English of Science and Technology for Automation

邢小军 吴 梅 编

西北工业大学出版社

【内容简介】 本书旨在使学生能够熟悉并掌握自动化技术方面的基本英语词汇，提高与自动化专业相关的英语文献的阅读能力，并促使学生掌握一定的相关专业的英语写作能力。其主要内容包括经典控制理论、现代控制理论、控制系统的稳定性分析、模糊控制、人工智能，以及运算放大器、低通滤波器等。

本书适合于自动化相关专业的本、专科生作为专业英语课程的教材，并有助于自动化专业技术人员提高阅读英文专业文献的能力。

图书在版编目（CIP）数据

自动化科技英语/邢小军，吴梅编．—西安：西北工业大学出版社，2007.8
ISBN 978-7-5612-2278-2

Ⅰ．自…　Ⅱ．①邢…　②吴…　Ⅲ．自动化技术—英语—高等学校—教材　Ⅳ．H31

中国版本图书馆 CIP 数据核字（2007）第 128962 号

出版发行：西北工业大学出版社
通信地址：西安市友谊西路 127 号　**邮编**：710072
电　　话：(029)88493844　88491757
网　　址：www.nwpup.com
印 刷 者：陕西友盛印务有限责任公司
开　　本：787 mm×1 092 mm　1/16
印　　张：9.625
字　　数：231 千字
版　　次：2007 年 8 月第 1 版　2007 年 8 月第 1 次印刷
定　　价：16.00 元

前　言

随着时代的发展，自动控制技术已渗透到人们工作和生活的各个方面。与之相关，自动化英语也随之独立成为一门专业外语，并在自动控制技术的应用中发挥着巨大的交流作用。

一个自动控制方面的人才除了要掌握自动化学科的基本理论和技能以外，同时还要具备快速获取新的自动化方面的知识的能力，而自动化英语（尤其是阅读能力）则是体现这种能力的一个重要方面。本着让学生读懂并了解相关课题，掌握必要的专业英语知识和专业术语，提高学生阅读自动化专业英语文献的能力的目的，本书的选材尽量选择概述性、介绍性文章。

本书特点如下：

·系统性：本书涵盖了自动控制技术多方面的内容，包括经典控制理论、现代控制理论、控制系统的稳定性分析等。同时考虑到自动化专业与电子技术等专业的学科交叉关系，还涉及部分电子技术方面的内容，如运算放大器、低通滤波器等。

·新颖性：本书体现出20世纪80年代到21世纪初关于自动化技术的成熟及最新技术，如模糊控制、人工智能等。

·代表性：本书选取的文章在内容上具有一定的代表性，基本体现了自动化专业的典型技术。

·广泛性：本书专业词汇的涵盖面广。

本书适合于自动化相关专业的本、专科生作为专业英语课程的教材，也可供从事于自动化领域的专业技术人员阅读参考。

本书由邢小军、吴梅编写。其中邢小军编写Unit 1～Unit 5，Unit 16～Unit 18，吴梅编写Unit 6～Unit 15。

由于编者水平有限，加之时间仓促，对于本书中出现的错误，欢迎广大读者批评指正。

编　者

2007年5月

CONTENTS

Unit 1 Operational Amplifier

1.1 Introduction

In this chapter, we will consider monolithic operational amplifiers (op amps) with single-ended outputs, both as an example of the utilization of the previously described circuit building blocks and as an introduction to the design and application of this important class of analog circuit.

An ideal op amp with a single-ended output has a differential input, infinite voltage gain, infinite input resistance, and zero output resistance. A conceptual schematic diagram is shown in Figure 1. 1. While actual op amps do not have these ideal characteristics, their performance is usually sufficiently good that the circuit behavior closely approximates that of an ideal op amp in most applications.

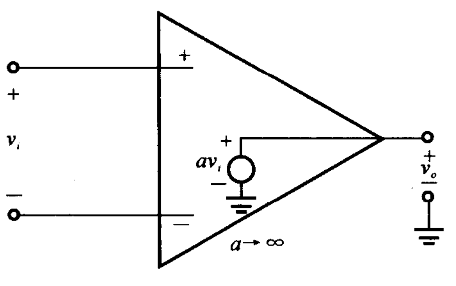

Figure 1. 1 Ideal operational amplifier

In op amps design, bipolar transistors offer many advantages over their CMOS counterparts, such as higher transconductance for a given current, higher gain ($g_m r_o$), higher speed; lower input-referred offset voltage and lower input-referred noise voltage. As a result, op amps made from bipolar transistors offer the best performance in many cases, including for example dc-coupled, low-offset, low-drift applications. For these reasons, bipolar op amps became commercially significant first and still usually offer superior analog performance. However, CMOS technologies have become dominant in building the digital portions of signal-processing systems because CMOS digital circuits are smaller and dissipate less power than their bipolar counterparts. Since these systems often operate on signals that originate in analog form, analog circuits such as op amps are required to interface to the digital CMOS circuits. To reduce system cost and increase portability, analog and digital circuits are now often integrated together, providing a strong economic incentive to use CMOS op amps.

In this chapter, we first explore several applications of op amps to illustrate their versatility in analog circuit and systems design. CMOS op amps are considered next. Then a general-purpose bipolar monolithic op amp, the 741, is analyzed, and the ways in which the performance of the circuit deviates from ideality are described. Design considerations for improving the various aspects of monolithic op-amps low-frequency performance are described.

1.2 Applications of Operational Amplifiers

1.2.1 Basic Feedback Concepts

Virtually all op-amp applications rely on the principles of feedback. We now consider a few basic concepts necessary for an understanding of op-amp circuits. A generalized feedback amplifier is shown in Figure 1. 2. The block labeled a is called the forward or basic amplifier, and the block labeled f is called the feedback network. The gain of the basic amplifier when the feedback network is not present is called the open-loop gain, a, of the amplifier. The function of the feedback network is to sense the output signal S_o and develop a feedback signal S_{fb}, which is equal to fS_o, where f is usually less than unity. This feedback signal is subtracted from the input signal S_i, and the difference S_ϵ is applied on the basic amplifier. The gain of the system when the feedback network is present is called the closed-loop gain. For the basic amplifier we have

$$S_o = aS_\epsilon = a(S_i - S_{fb}) = a(S_i - fS_o) \tag{1.1}$$

and thus

$$\frac{S_o}{S_i} = \frac{a}{1+af} = \frac{1}{f}\left(\frac{a}{1+af}\right) = \frac{1}{f}\left(\frac{T}{1+T}\right) \tag{1.2}$$

where $T = af$ is called the loop gain. When T becomes large compared to unity, the closed-loop gain becomes

$$\lim_{T\to\infty} \frac{S_o}{S_i} = \frac{1}{f} \tag{1.3}$$

Since the feedback network is composed of passive components, the value of f can be set to an arbitrary degree of accuracy and will establish the gain at a value of $1/f$ if $T \gg 1$, independent of any variations in the open-loop gain a. This independence of closed-loop performance from the parameters of the active amplifier is the primary factor motivating the wide use of op amps as active elements in analog circuits.

For the circuit shown in Figure 1. 2, the feedback signal tends to reduce the magnitude of S_ϵ below that of the open-loop case (for which $f=0$) when a and f have the same sign. This case is called negative feedback and is the case of practical interest in this chapter.

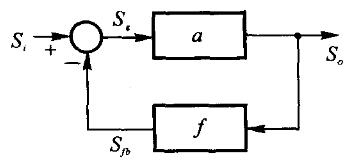

Figure 1. 2 A conceptual feedback amplifier

With this brief introduction to feedback concepts, we proceed to a consideration of several examples of useful op-amp configurations. Because these example circuits are simple, direct analysis with Kirchoff's laws is easier than attempting to consider them as feedback amplifiers.

1. 2. 2 Inverting Amplifier

The inverting amplifier connection is shown in Figure 1. 3 (a). We assume that op-amp input resistance is infinite, and that the output resistance is zero as shown in Figure 1. 1 from KCL at node X,

$$\frac{V_s - V_i}{R_1} + \frac{V_o - V_i}{R_2} = 0 \tag{1.4}$$

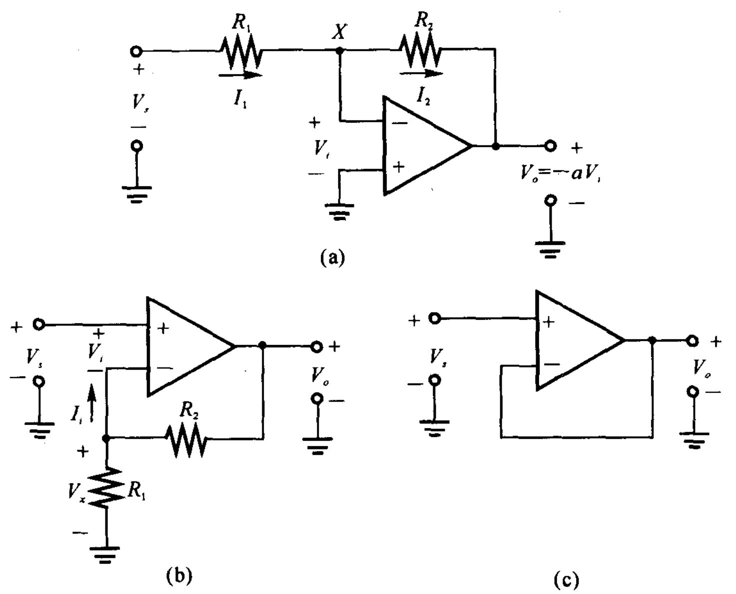

Figure 1. 3

(a) Inverting amplifier configuration; (b) Noninverting amplifier configuration; (c) Voltage-follower configuration

Since R_2 is connected between the amplifier output and the inverting input, the feedback is negative. Therefore, V_i would be driven to zero with infinite open-loop gain. On the other hand, with finite open-loop gain a,

$$V_i = \frac{-V_o}{a} \tag{1.5}$$

Substituting (1.5) and (1.4) and rearranging gives

$$\frac{V_o}{V_s} = -\frac{R_2}{R_1}\left[\frac{1}{1+\frac{1}{a}\left(1+\frac{R_2}{R_1}\right)}\right] \tag{1.6}$$

If the gain of the op amp is large enough that

$$a\left(\frac{R_1}{R_1+R_2}\right) \gg 1 \tag{1.7}$$

then the closed-loop gain is

$$\frac{V_o}{V_s} \approx -\frac{R_2}{R_1} \tag{1.8}$$

When the inequality in (1.7) holds, (1.8) shows that the closed-loop gain depends primarily on the external passive components R_1 and R_2. Since these components can be selected with arbitrary accuracy, a high degree of precision can be obtained in closed-loop performance independent of variations in the active device (op-amp) parameters. For example, if the op-amp gain were to change from 5×10^4 to 10^5, this 100 percent increase in gain would have almost no observable effect on closed-loop performance provided that (1.7) is valid.

The large gain of op amps allows the approximate analysis of circuits like that of Figure 1.3(a) to be performed by the use of summing-point constraints. If the op amp is connected in a negative-feedback circuit, and if the gain of the op amp is very large, then for a finite value of output voltage the input voltage must approach zero since

$$V_i = -\frac{V_o}{a} \tag{1.9}$$

Thus one can analyze such circuits approximately by assuming a priori that the op-amp input voltage is driven to zero. An implicit assumption in doing so is that the feedback is negative, and that the circuit has a stable operating point at which (1.10) is valid.

The assumption that $V_i = 0$ is called a summing-point constraint. A second constraint is that no current can flow into the op-amp input terminals, since no voltage exists across the input resistance of the op amp if $V_i = 0$. This summing-point approach allows an intuitive understanding of the operation of the inverting amplifier configuration of Figure 1.3(a). Since the inverting input terminal is forced to ground potential, the resistor R_1 servers to convert the voltage V_s to an input current of value V_s/R_1. This current cannot flow in the input terminal of an ideal op amp; therefore, it flows through R_2, producing a voltage drop of V_sR_2/R_1. Because the op-amp input terminal operates at ground potential, the input resistance of the overall circuit as seen by V_s is equal to R_1. Since the inverting input of the amplifier is forced to ground potential by the negative feedback, it is sometimes called a virtual ground.

1.2.3 Noninverting Amplifier

The noninverting amplifier is shown in Figure 1.3(b). Using Figure 1.1, assume that no current flows into the inverting op-amp input terminal. If the open-loop gain is a, $V_i = V_o/a$ and

$$V_x = V_o\left(\frac{R_1}{R_1+R_2}\right) = V_s - \frac{V_o}{a} \tag{1.10}$$

Rearranging (1.10) gives

$$\frac{V_o}{V_s} = \left(1+\frac{R_2}{R_1}\right)\frac{\dfrac{aR_1}{R_1+R_2}}{1+\dfrac{aR_1}{R_1+R_2}} \approx \left(1+\frac{R_2}{R_1}\right) \tag{1.11}$$

The approximation in (1.11) is valid to the extent that $aR_1/(R_1+R_2) \gg 1$.

In contrast to the inverting case, this circuit displays a very high input resistance as seen by V_s because of the type of feedback used. Also unlike the inverting case, the noninverting connection causes the common-mode input voltage of the op amp to be equal to V_s. An important variation of this connection is the voltage flower, in which $R_1 \rightarrow \infty$ and $R_2 = 0$. This circuit is shown in Figure 1.3(c), and its gain is close to unity if $a \gg 1$.

1.2.4 Differential Amplifier

The differential amplifier is used to amplify the difference between two voltages. The circuit is shown in Figure 1.4. For this circuit, $I_{i1} = 0$ and thus resistors R_1 and R_2 form a voltage divider. Voltage V_x is then given by

$$V_x = V_1\left(\frac{R_2}{R_1+R_2}\right) \tag{1.12}$$

The current I_1 is

$$I_1 = \left(\frac{V_2 - V_y}{R_1}\right) = I_2 \tag{1.13}$$

The output voltage is given by

$$V_o = V_y - I_2R_2 \tag{1.14}$$

If the open-loop gain is infinite, the summing-point constraint that $V_i = 0$ is valid and forces $V_y = V_x$. Substituting $V_y = V_x$, (1.12), and (1.13) into (1.14) and rearranging gives

$$V_o = \frac{R_2}{R_1}(V_1 - V_2) \tag{1.15}$$

The circuit thus amplifiers the difference voltage($V_1 - V_2$).

Differential amplifiers are often required to detect and amplify small differences between two sizable voltages. For example, a typical application is the measurement of the difference voltage between the two arms of a Wheatstone bridge. As in the case of the noninverting amplifier, the op amp of Figure 1.4 experiences a common-mode input that is almost equal to the common-mode voltage $(V_1+V_2)/2$ applied to the input terminals when $R_1 = R_2$.

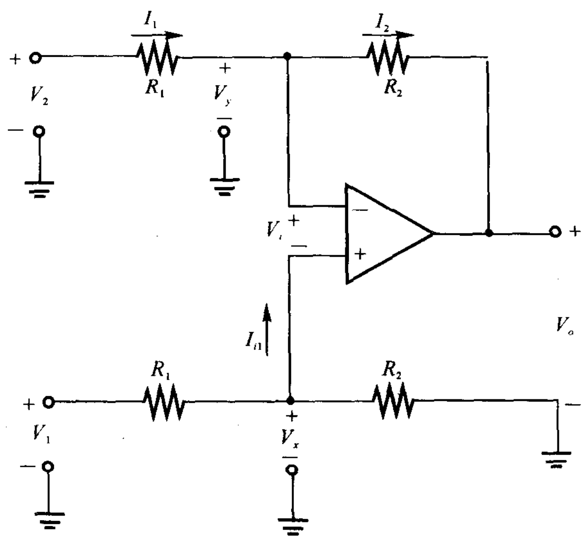

Figure 1.4 Differential amplifier configuration

1.2.5 Nonlinear Analog Operations

By including nonlinear elements in the feedback network, op amps can be used to perform nonlinear operations on one or more analog signals. The logarithmic amplifier, shown in Figure 1. 5, is an example of such an application. Log amplifiers find wide application in instrumentation systems where signals of very large dynamic range must be sensed and recorded. The operation of this circuit can again be understood by application of the summing-point constrains. Because the input voltage of the op amp must be zero, the resistor R serves to convert the input voltage V_s into a current. This same current must then flow into the collector of the transistor. Thus the circuit forces the collector current of the transistor to be proportional to the input voltage. Furthermore, the transistor operates in the forward-active region because $V_{CB} \approx 0$. Since the base-emitter voltage of a bipolar transistor in the forward-active region is logarithmically related to the collector current and since the output voltage is just the emitter-base voltage of the transistor, a logarithmic transfer characteristic is produced. In terms of equations

$$I_1 = \frac{V_s}{R} = I_c = I_s\left[\exp\left(\frac{V_{be}}{V_T}\right) - 1\right] = I_s\exp\left(\frac{V_{be}}{V_T}\right) \tag{1.16}$$

and

$$V_o = -V_{be} \tag{1.17}$$

Thus

$$V_o = -V_T\ln\left(\frac{V_s}{I_sR}\right) \tag{1.18}$$

The log amplifier is only one example of a wide variety of op-amp applications in which a nonlinear feedback element is used to develop a nonlinear transfer characteristic. For example, two log amplifiers can be used to develop the logarithm of two different signals. These voltages can be summed, and then the exponential function of the result can be developed using an inverting amplifier connection with R_1 replaced with a diode. The result is an analog multiplier. Other nonlinear operations such as limiting, rectification, peak detection, squaring, square rooting, raising to a power, and division can be performed in conceptually similar ways.

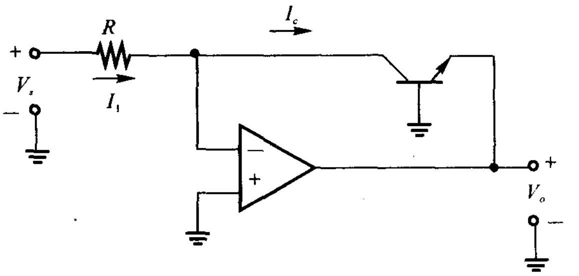

Figure 1.5 Logarithmic amplifier configuration

1.2.6 Integrator, Differentiator

The integrator and differentiator circuit, shown in Figure 1.6, are examples of using op amps with reactive elements in the feedback network to realize a desired frequency response or time-domain response. In the case of the integrator, the resistor R is used to develop a current I_1 that is proportional to the input voltage. This current flows into the capacitor C, whose voltage is proportional to the integral of the current I_1 with respect to time. Since the output voltage is equal to the negative of the capacitor voltage, the output is proportional to the integral of the input voltage with respect to time. In terms of equations,

$$I_1 = \frac{V_s}{R} = I_2 \tag{1.19}$$

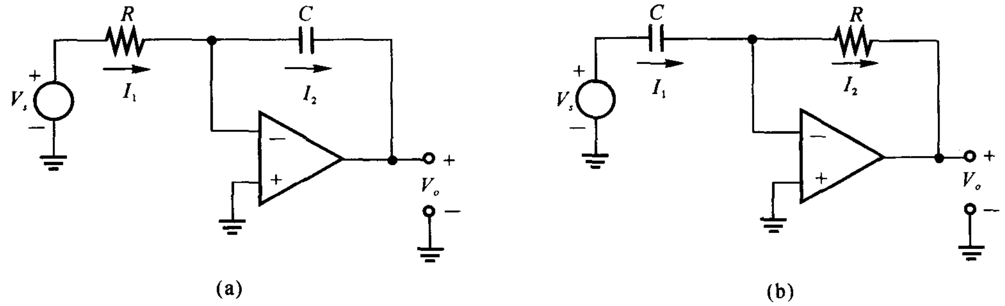

Figure 1.6

(a) Integrator configuration; (b) Differentiator configuration

and

$$V_o = -\frac{1}{C}\int_0^t I_2 \, d\tau + V_o(0) \tag{1.20}$$

Combining (1.19) and (1.20) yields

$$V_o(t) = -\frac{1}{RC}\int_0^t V_s(\tau)\mathrm{d}\tau + V_o(0) \tag{1.21}$$

The performance limitations of real op amps limit the range of V_o and the rate of change of V_o for which this relationship is maintained.

In the case of the differentiator, the capacitor C is connected between V_s and the inverting op-amp input. The current through the capacitor is proportional to the time derivative of the voltage across it, which is equal to the input voltage.

This current flows through the feedback resistor R, producing a voltage at the output proportional to the capacitor current, which is proportional to the time rate of change of the input voltage. In terms of equations,

$$I_1 = C\frac{\mathrm{d}V_s}{\mathrm{d}t} = I_2 \tag{1.22}$$

$$V_o = -RI_2 = -RC\frac{\mathrm{d}V_s}{\mathrm{d}t} \tag{1.23}$$

Words and Phrases

monolithic 单片电路，单块集成电路
bipolar transistor 双极型晶体管
transconductance 跨导
passive component 无源元件
Kirchoff's laws 基尔霍夫定律
inverting amplifier 反相放大器
virtual ground 虚拟地
noninverting amplifier 同相放大器
common-mode input voltage 共模输入电压
voltage flower 电压跟随器
differential amplifier 差动放大器
Wheatstone bridge 惠斯通电桥
logarithmic amplifier 对数放大器
integrator 积分器
differentiator 微分器
KCL—Kirchoff's current laws 基尔霍夫电流定律

Notes

1. An ideal op amp with a single-ended output has a differential input, infinite voltage gain, infinite input resistance, and zero output resistance.

单端输出的理想运算放大器具有差分输入，无穷大的电压增益，无穷大输入阻抗，0 输出阻抗。

2. When the inequality in (1.7) holds, (1.8) shows that the closed-loop gain depends

primarily on the external passive components R_1 and R_2.

当(1.7)不等式成立时，从(1.8)可以看出闭环增益主要取决于外部无源器件 R_1 和 R_2。

Exercises

Ⅰ. Directions: choose the appropriate answer for the following questions.

1. Which of the following characteristics does not necessarily apply to an op-amp?

(a) High gain

(b) low power

(c) High input impendance

(d) Low output impendance

2. For an op-amp with negative feedback, the output is

(a) equal to the input

(b) increased

(c) fed back to the inverting input

(d) fed back to the noninverting input

3. The use of negative feedback

(a) reduces the voltage gain of an op-amp

(b) makes the op-amp oscillate

(c) makes linear operation possible

(d) answers (a) and (c)

4. A certain noninverting amplifier has an R_1 of 1.0 kΩ and an R_2 of 100 kΩ. The closed-loop gain is

(a)100,000 (b)1000 (c) 101 (d)100

5. A voltage follower

(a) has a gain of one

(b) is noninverting

(c) has no feedback resistor

(d) answers (a),(b)and(c)

6. With zeros volts on both inputs, an op-amp ideally should have an output

(a) equal to the positive supply voltage

(b) equal to the negative supply voltage

(c) equal to zero

(d) equal to the CMRR

Ⅱ. Directions: Answer the following questions.

1. What is the main purpose of negative feedback?

2. What are the differences between a practical op-amp and the ideal?

Ⅲ. Directions: Calculate the gain of the circuit Figure 1.3(a), for $a=10^4$ and $a=10^5$, and $R_1=1$ kΩ, $R_2=$ 10 kΩ.

Unit 2 Low-Pass Filters

2.1 First-Order Filters

An integrator (Figure 2.1(a)) is the simplest filter mathematically, and it forms the building block for most modern integrated filters. Consider what we know intuitively about an integrator. If you apply a DC signal at the input (i.e., zero frequency), the output will describe a linear ramp that grows in amplitude until limited by the power supplies. Ignoring that limitation, the response of an integrator at zero frequency is infinite, which means that it has a pole at zero frequency. (A pole exists at any frequency for which the transfer function's value becomes infinite.)

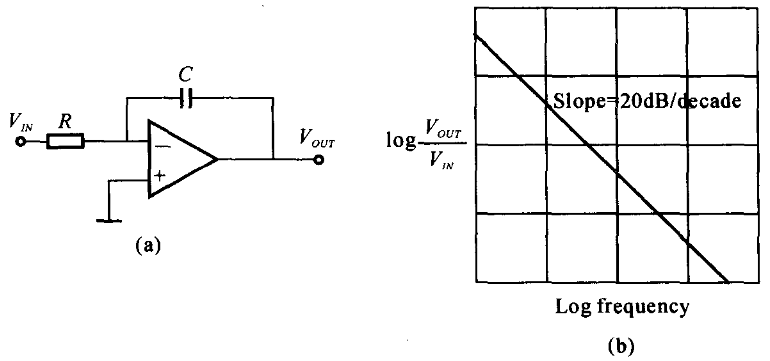

Figure 2.1

(a) A simple RC integrator; (b) A Bode plot of a simple integrator

We also know that the integrator's gain diminishes with increasing frequency and that at high frequencies the output voltage becomes virtually zero. Gain is inversely proportional to frequency, so it has a slope of -1 when plotted on log/log coordinates (i.e., -20dB/decade on a Bode plot, Figure 2.1(b)).

You can easily derive the transfer function as

$$\frac{V_{OUT}}{V_{IN}} = \frac{X_C}{R} = \frac{1/sC}{R} = \frac{\omega_0}{s} \tag{2.1}$$

where s is the complex-frequency variable $\sigma + j\omega$ and ω_0 is $1/RC$. If we think of s as frequency, this formula confirms the intuitive feeling that gain is inversely proportional to frequency.

The next most complex filter is the simple low-pass RC type (Figure 2. 2(a)). Its characteristic (transfer function) is

$$\frac{V_{OUT}}{V_{IN}} = \frac{1/sC}{R + 1/sC} = \frac{1}{1 + sCR} = \frac{\omega_0}{s + \omega_0} \qquad (2.2)$$

When $s = 0$, the function reduces to ω_0/ω_0, i. e., 1. When s tends to infinity, the function tends to zero, so this is a low-pass filter. When $s = -\omega_0$, the denominator is zero and the function's value is infinite, indicating a pole in the complex frequency plane. The magnitude of the transfer function is plotted against s in Figure 2. 2(b), where the real component of s (σ) is toward us and the positive imaginary part ($j\omega$) is toward the right. The pole at $-\omega_0$ is evident. Amplitude is shown logarithmically to emphasize the function's form. For both the integrator and the RC low-pass filter, frequency response tends to zero at infinite frequency; that is, there is a zero at $s = \infty$. This single zero surrounds the complex plane.

But how does the complex function in s relate to the circuit's response to actual frequencies? When analyzing the response of a circuit to AC signals, we use the expression $j\omega L$ for impedance of an inductor and $1/j\omega C$ for that of a capacitor. When analyzing transient response using Laplace transforms, we use sL and $1/sC$ for the impedance of these elements. The similarity is apparent immediately. The $j\omega$ in AC analysis is in fact the imaginary part of σ, which, as mentioned earlier, is composed of a real part σ and an imaginary part $j\omega$.

If we replace s by $j\omega$ in any equation so far, we have the circuit's response to an angular frequency. In the complex plot in Figure 2. 2(b), $\sigma = 0$ and hence $s = j\omega$ along the positive j axis. Thus, the function's value along this axis is the frequency response of the filter. We have sliced the function along the $j\omega$ axis and emphasized the RC low-pass filter's frequency response curve by adding a heavy line for function values along the positive j axis. The more familiar Bode plot (Figure 2. 2(c)) looks different in form only because the frequency is expressed logarithmically.

While the complex frequency's imaginary part ($j\omega$) helps describe a response to AC signals, the real part (σ) helps describe a circuit's transient response. Looking at Figure 2. 2(b), we can therefore say something about the RC low-pass filter's response as compared to that of the integrator. The low-pass filter's transient response is more stable, because its pole is in the negative-real half of the complex plane. That is, the low-pass filter makes a decaying-exponential response to a step-function input; the integrator makes an infinite response. For the low-pass filter, pole positions further down the $-\sigma$ axis mean a higher ω_0, a shorter time constant, and therefore a quicker transient response. Conversely, a pole closer to the j axis causes a longer transient response.

So far, we have related the mathematical transfer functions of some simple circuits to their associated poles and zeroes in the complex-frequency plane. From these functions, we have derived the circuit's frequency response (and hence its Bode plot) and also its transient response. Because both the integrator and the RC filter have only one s in the denominator of their transfer functions, they each have only one pole. That is, they are first-order filters.

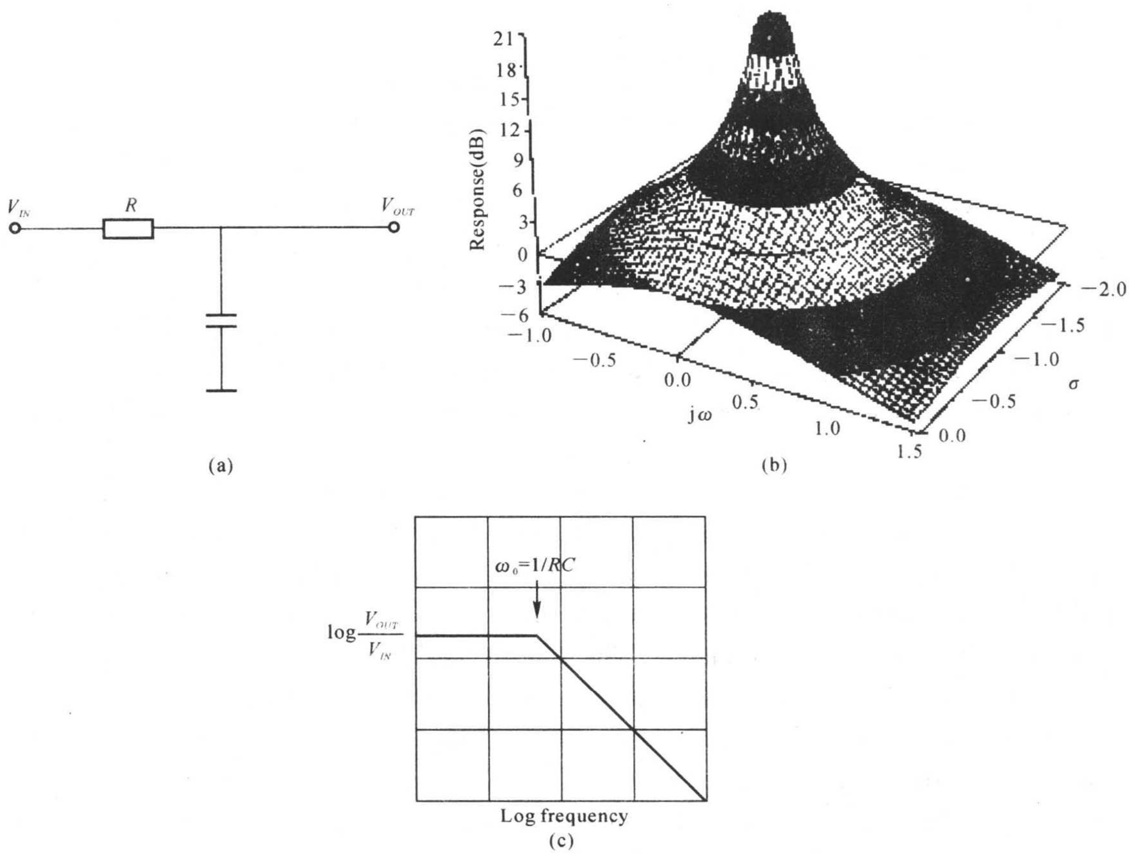

Figure 2.2

(a) A simple RC low-pass filter; (b) The complex function of an RC low-pass filter

(c) A Bode plot of a low-pass filter

However, as we can see from Figure 2.1(b), the first-order filter does not provide a very selective frequency response. To tailor a filter more closely to our needs, we must move on to higher orders. From now on, we will describe the transfer function using $f(s)$ rather than the cumbersome V_{OUT}/V_{IN}.

2.2 Second-Order Low-Pass Filters

A second-order filter has s^2 in the denominator and two poles in the complex plane. You can obtain such a response by using inductance and capacitance in a passive circuit or by creating an active circuit of resistors, capacitors, and amplifiers. Consider the passive LC