Unit 4

Section A　Operational Amplifiers

1. Introduction

Amplifiers are electronic devices used to produce output signals that are magnified copy of small input signals. The ratio of an amplifier's output signal to its input signal is referred to as *gain*. **An operational amplifier, commonly known as "op-amp", is a DC-coupled high-gain electronic voltage amplifier with differential inputs (we'll discuss differential input later) and, usually, a single output.**[1] High input impedance at the input terminals (ideally infinite) and low output impedance (ideally zero) are important typical characteristics. Originally, the term, "Operational Amplifier, " was used in the computing field to describe amplifiers that performed various mathematical operations. **It was found that the application of negative feedback around a high gain DC amplifier would produce a circuit with a precise gain characteristic that depended only on the feedback used.**[2] By the proper selection of feedback components, operational amplifier circuits could be used to add, subtract, average, integrate, and differentiate. This gives rise to the name "Operational Amplifier".

Typically, an operational amplifier has six terminals, as is shown in Fig. 4-A-1.

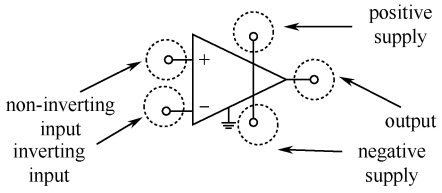

Fig. 4-A-1　Symbol for an Op-amp and the names of its terminals.

The input denoted with a "+" is called the *non-inverting terminal*, the other input denoted with a "−"is called the *inverting terminal*. There are generally two power terminals (sometimes only one) called *positive supply* and *negative supply* respec-tively. Often, a *ground terminal* is necessary. And there is also an *output terminal*. For simplicity, the power terminals and ground terminal could be omitted, leaving an op-amp only its inputs and output (as is illustrated in Fig. 4-A-2).

Note that in application, an op-amp is often times pictured with the inverting input at the top and the non-inverting input at the bottom (as is illustrated in Fig. 4-A-3). This makes the schematic simpler but could cause confusion if not enough attention is paid.

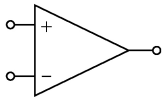

Fig. 4-A-2　Simpler version of an Op-amp symbol.

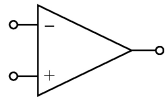

Fig. 4-A-3　Another symbol for an Op-amp.

The amplifier's differential inputs consist of a V_+ (non-inverting) input and a V_- (inverting) input, and generally the op-amp amplifies only the difference in voltage between the two. This is called the *differential input voltage*. If no other circuit is attached to the op-amp (i.e., there is no feedback), then the amplifier is said to be in an *open loop* configuration, and its output is the differential input voltage multiplied by the total gain of the amplifier. That is, for the open loop operational amplifier,

$$V_{\mathrm{OUT}} = (V_+ - V_-)A_{\mathrm{OL}} \tag{4-A-1}$$

where V_+ is the voltage at the non-inverting terminal, V_- is the voltage at the inverting terminal and A_{OL} is the total open-loop gain of the amplifier.

Because the magnitude of the open-loop gain is typically very large, open-loop operation results in op-amp saturation unless the differential input voltage is extremely small. Finley's law states that "When the inverting and non-inverting inputs of an op-amp are not equal, its output is in saturation." Additionally, the precise magnitude of this gain is not well controlled by the manufacturing process, and so it is impractical to use an operational amplifier as a stand-alone differential amplifier. Instead, op-amps are usually used in negative-feedback configurations.

2. Ideal Op-amps

There is no such thing as an ideal op-amp, but present day op-amps come so close to ideal that *Ideal Op-amp* analysis approaches actual analysis. In addition, when working at low frequencies, several kHz, the ideal op-amp analysis produces accurate answers. **In this and the following section, we will employ Ideal Op-amp analysis continuously to help you understand the basic principles that help in digging into the properties of the real devices and investigating circuits utilizing practical operational amplifiers later by yourself.**[3]

In order to introduce operational amplifier circuitry, we will use an ideal model of the operational amplifier to simplify the mathematics involved in deriving gain expressions, etc., for the circuits presented (as is illustrated in Fig. 4-A-4). Internally, an operational amplifier can be modeled using resistors and a cont-rolled voltage source.

The controlled voltage source produces a scaled output proportional to the voltage across R_{IN}. That is, the value of the output voltage has nothing to do with the output load, which means the amplifier has zero output impedance. The input impedance R_{IN} is infinite, thus we assume no current flows into the inputs.

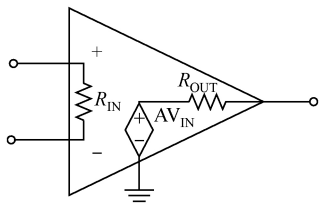

Fig. 4-A-4 Ideal Op-amp model.

Operational amplifiers are almost always used with negative feedback, in which part of the op-amp output signal is returned to the input in opposition to the source signal.[4] For an ideal op-amp, we assume that the open-loop gain A_{OL} approaches infinity, and then even a very tiny differential input voltage results in a very large output voltage. In a negative-feedback circuit, the feedback network returns a fraction of the output to the infinite gain, the differential input voltage is driven to zero exactly (i.e. the non-inverting input has the same potential with the inverting input). Recall that no current flows into the input terminals, we get

$$V_+ = V_- \tag{4-A-2}$$

$$I_+ = I_- = 0 \tag{4-A-3}$$

These equations are the most fundamental ideal op-amp equations and will be used from time to time in the section that followed.

To summarize, an ideal op-amp has the following attributes:

- Infinite input impedance
- Zero output impedance
- Infinite differential gain
- Zero offset voltage (which leads to $V_+ = V_-$)
- Zero bias current (which leads to $I_+ = I_- = 0$)

There are also more attributes of an ideal op-amp such as infinite bandwidth and zero gain for common-mode input.[5] You may investigate these by referring to more in-depth books.

New Words

operational [ˌɔpəˈreiʃənəl]　*adj.* 运算的，操作的
amplifier [ˈæmplifaiə]　*n.* 放大器，扩音器
device [diˈvais]　*n.* 装置，设备，器件
magnify [ˈmægnifai]　*vt.* 放大，扩大
ratio [ˈreiʃiəu]　*n.* 比例，比率
gain [gein]　*n.* 增益
couple [ˈkʌpl]　*n.* 耦合，连接
differential [ˌdifəˈrenʃəl]　*n.* 差动的，微分的
impedance [imˈpi:dəns]　*n.* 阻抗
terminal [ˈtə:minəl]　*n.* 接线端，终端
ideally [aiˈdiəli]　*n.* 理想地，完美地
infinite [ˈinfinət]　*adj.* 无穷的，无限的，极大的
characteristic [ˌkærəktəˈristik]　*n.* 特性，特征
originally [əˈridʒənəli]　*adv.* 最初，原先
mathematical [ˌmæθiˈmætikəl]　*adj.* 数学的，精确的
feedback [ˈfi:dbæk]　*n.* 反馈，反应，回授
component [kəmˈpəunənt]　*n.* 成分，零件，要素
integrate [ˈintigreit]　*vt.* 求……的积分
differentiate [ˌdifəˈrenʃieit]　*vt.* 求……的微分
denote [diˈnəut]　*vt.* 指示，表示
invert [inˈvə:t]　*vt.* 使颠倒，使转化
respectively [riˈspektivli]　*adv.* 分别地，各个地
illustrate [ˈiləstreit]　*vt.* 图解，举例说明
schematic [ski:ˈmætik]　*n.* 原理图，示意图
confusion [kənˈfju:ʒən]　*n.* 混淆，混乱
attach [əˈtætʃ]　*vt.* 附加，使联系
magnitude [ˈmægnitju:d]　*n.* 数量，大小，量级
saturation [ˌsætʃəˈreiʃən]　*n.* 饱和

manufacture [ˌmænjuˈfæktʃə] *vt.* 制造，加工
configuration [kən, figjuˈreiʃən] *n.* 组态
utilize [ˈju:tilaiz] *vt.* 利用，使用
derive [diˈraiv] *vt.* 推理出，得自
proportional [prəuˈpɔ:ʃənəl] *adj.* 成比例的，均衡的
fraction [ˈfrækʃən] *n.* 小部分，片段，分数
potential [pəuˈtenʃəl] *n.* 电势，电压
attribute [əˈtribju:t] *n.* 属性，品质，特征
bandwidth [ˈbændwidθ] *n.* 带宽

Phrases

Operational amplifier 运算放大器
op-amp 运放（运算放大器的简称）
differential inputs 差分输入
negative feedback 负反馈
non-inverting terminal 非反向端
inverting terminal 反向端
positive supply 正极电源
negative supply 负极电源
open loop 开环
Ideal Op-amp analysis 理想运放分析法
controlled voltage source 受控电压源
output impedance 输出阻抗
offset voltage 失调电压
bias current 偏移电流

Notes

1. An operational amplifier, commonly known as “op-amp”, is a DC-coupled high-gain electronic voltage amplifier with differential inputs (we’ll discuss differential input later) and, usually, a single output.

运算放大器，通常简称为“运放”，是一种直流耦合的、高增益的、有两个差分输入端（后文将提到差分输入）且通常有一个输出端的电压放大器。

2. It was found that the application of negative feedback around a high gain DC amplifier would produce a circuit with a precise gain characteristic that depended only on the feedback used.

人们发现在高增益直流放大器周围使用负反馈可以产生一种带有精确增益特性的电路，且该特性仅依赖于所用的反馈网络。

3. In this and the following section, we will employ Ideal Op-amp analysis continuously to help you understand the basic principles that help in digging into the properties of the real devices later by yourselves and investigating circuits utilizing practical operational amplifiers later by yourself.

在本节及后面的章节中，我们将持续使用理想运放分析法来帮助读者理解一些基本原理，以便读者以后能够自己发掘实际器件的特性，直至最终能够分析使用实际运放的电路。

4. Operational amplifiers are almost always used with negative feedback, in which part of the op-amp output signal is returned to the input in opposition to the source signal.

运算放大器几乎总是与负反馈联合使用。在负反馈中，运放的部分输出信号被返回到输入端并削弱了源端信号。

5. There are also more attributes of an ideal op-amp such as infinite bandwidth and zero gain for common-mode input.

理想运放还有很多属性，如共模输入的无限带宽和零增益。

Exercises

[EX.1] Discussion.

1. Does the gain change if the frequency of the input signal changes?

2. What are the two power supplies' role in op-amp?

3. Is ideal op-amp useful in practical analysis?

[EX.2] Translate the following passages into Chinese.

1. An amplifier with the general characteristics of very high voltage gain, very high input resistance, and very low output resistance generally is referred to as an Op-Amp.

2. Power pins are often omitted from the schematic symbol when the power supply voltages are explicit elsewhere in the schematic.

3. The operational amplifier can be represented by an ideal voltage source whose value depends on the input voltage appearing across the inverting and non-inverting inputs plus the effects of finite input and output impedances.

4. The simplified model of the differential output operational amplifier is an accurate approximation only under special conditions of feedback.

5. The output impedance of the ideal operational amplifier is assumed to be zero. It then can supply as much current as necessary to the load being driven.

6. The amplifier output will be zero when a zero signal appears between the inverting and non-inverting inputs.

7. An important by-product of these properties of the ideal operational amplifier is that the summing point, the inverting input, will conduct no current to the amplifier.

8. The gain of an ideal op-amp is assumed to be infinite, hence it drives the output voltage to any value to satisfy the input conditions.

9. The ideal op-amp can drive any load without an output impedance dropping voltage across it.

10. An electrical signal applied at the amplifier input does not appear instantaneously at the amplifier output; there is a finite 'propagation time' between input and output.

11. One problem with electronic devices corresponding to the generalized amplifiers is that the gains, AU or AI, depend upon internal properties of two – port system (m, b, RI, Ro, et.al.). This makes design difficult since these parameters usually vary from device to device, as well as temperature.

[EX.3] Translate the following passages into English.

1. 放大器是具有两个差分输入端和一个单端输出的直流耦合型器件。

2. 运算放大器是一种高阻抗、高增益器件，常被用来放大小信号。

3. 由于电压增益为无限大，一个无限小的输入信号即可放大为一个很大的输出信号。
4. 运放有两种基本组态：反相组态和同相组态。
5. 通常，运放的输出由负反馈或者正反馈控制。
6. 输入端的高阻抗和低输出阻抗是运放的重要典型特征。
7. 按常规生产数量算，许多标准集成电路运放的成本只有几分钱；然而一些带有特殊性能规格的集成运放或混合运放即使很小的数量其成本也要 100 多美元。
8. 现代设计产品在电子性能上比早期的实物更为耐用，有些甚至可以在输出端直接短路而完好无损。
9. 运算放大器常与反馈环合用，在反馈环中放大器的输出会影响某一个输入。
10. 在其最常见的用法中，运放通过将输出信号的一小部分送回到反向输入端来控制输出电压，这就给放大器提供了负反馈。

[EX.4] Fill out the spaces after the record.

Amplifier are devices that produce__1__input signals. The__2__is the amplification ratio of the output signal to its input signals. Operational amplifiers are often called__3__, they usually have__4__inputs. An op-amp has__5__input impedance and__6__output impedance. An ideal op-amp has__7__input impedance and__8__output impedance. In an ideal op-amp, we could assume that no__9__flows into the input. Op-amps are often used with__10__feedback.

Section B The Applications of Operational Amplifiers

Operational amplifiers are usually used with feedback loops where the output of the amplifier would influence one of its inputs. **In its most common use, the op-amp's output voltage is controlled by feeding a fraction of the output signal back to the *inverting input,* which provides negative feedback to the amplifier.** [1] In the following text, several typical op-amp application circuits will be provided to show you how the op-amp functions with feedback network.

1. The Non-inverting Op-amp

Non-inverting Op-amp is shown in Fig. 4-B-1.

The non-inverting op-amp has the input signal connected to its non-inverting input, thus its input source sees infinite impedance.[2] As we know, the negative input must be at the same voltage as the positive input, i.e. $V_+ = V_- = 0$. The op-amp output drives current into R_2 until the negative input is at the voltage, V_{IN}. This action causes V_{IN} to appear across R_1. The voltage divider rule is used to calculate V_{IN}; V_{OUT} is the input to the voltage divider, and V_{IN} is the output of the voltage divider. Since no current can flow into either op-amp lead, use of the voltage divider rule is allowed. Eq. (4-B-1) is written with the aid of the voltage divider rule, and algebraic manipulation yields Eq. (4-B-1) in the form of a gain parameter.

$$V_{IN} = V_{OUT} \frac{R_1}{R_1 + R_2} \tag{4-B-1}$$

$$A = \frac{V_{OUT}}{V_{IN}} = \frac{R_1 + R_2}{R_1} = 1 + \frac{R_2}{R_1} \tag{4-B-2}$$

When R_2 becomes zero or R_1 becomes very large with respect to R_2, $(R_2/R_1) \rightarrow 0$. Then we get the minimum gain magnitude, unity. The resulting circuit is called a voltage follower. Usually, we choose R_1 to be an open circuit for a voltage follower.

Notice that the gain is only a function of the feedback and gain resistors; the feedback has accomplished its function of making the gain independent of the op-amp parameters. **The gain is adjusted by varying the ratio of the resistors. The actual resistor values are determined by the impedance levels that the designer wants to establish.**[3] If R_2 = 10 kΩ and R_1 = 10 kΩ the gain is two as shown in Eq. (4-B-2), and if R_2 = 100 kΩ and R_1 = 100 kΩ the gain is still two. The impedance levels of 10 kΩ or 100 kΩ determine the current drain, the effect of stray capacitance, and a few other points. The impedance level does not set the gain; the ratio of R_2/R_1 does.

2. The Inverting Op-amp

Inverting Op-amp is shown in Fig. 4-B-2.

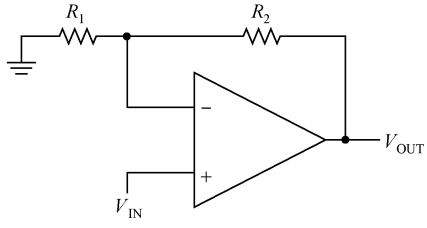

Fig. 4-B-1　Non-inverting Op-amp.

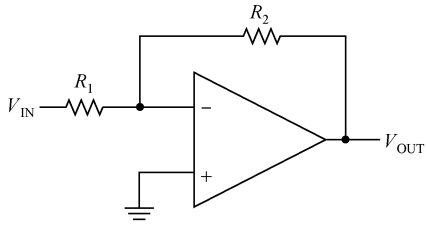

Fig. 4-B-2　Inverting Op-amp (Inverter).

The non-inverting input of the inverting op-amp (inverter) circuit is grounded. **One assumption made is that the input offset voltage is zero, so the feedback keeps inverting the input of the op-amp at a virtual ground (not actual ground but acting like ground).**[4] The current flow in the input leads is assumed to be zero; hence the current flowing through R_1 equals the current flowing through R_2. Using Kirchoff's law, we write Eq. (4-B-3); and the minus sign is inserted because this is the inverting input. Algebraic manipulation gives Eq. (4-B-4).

$$I_1 = \frac{V_{IN}}{R_1} = -I_2 = -\frac{V_{OUT}}{R_2} \tag{4-B-3}$$

$$A = \frac{V_{OUT}}{V_{IN}} = -\frac{R_2}{R_1} \tag{4-B-4}$$

Notice that the gain is only a function of the feedback and gain resistors, so the feedback has accomplished its function of making the gain independent of the op-amp parameters. The actual resistor values are determined by the impedance levels that the designer wants to establish. If R_2 = 10 kΩ and R_1 = 10 kΩ the gain is minus one as shown in Eq.(4-B-5), and if R_2 = 100 kΩ and R_1 = 100 kΩ the gain is still minus one. **The impedance levels of 10 kΩ or 100 kΩ determine the current drain, the effect of stray capacitance, and a few other points.**[5] The impedance level does not set the gain; the ratio of R_2/R_1 does.

One final note: the output signal is the input signal amplified and inverted. The circuit input impedance is set by R_1 because the inverting input is held at a virtual ground.

3. The Adder

An adder circuit can be made by connecting more inputs to the inverting op-amp (see Fig. 4-B-3). The opposite end of the resistor connected to the inverting input is held at virtual ground by the feedback; therefore, adding new inputs does not affect the response of the existing inputs.

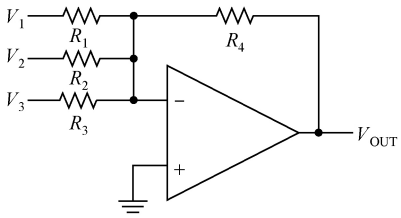

Fig. 4-B-3 Adder.

Superposition is used to calculate the output voltages resulting from each input, and the output voltages are added algebraically to obtain the total output voltage. Eq. (4-B-5) is the output equation when V_1 and V_2 are grounded. Eqs. (4-B-6) and (4-B-7) are the other superposition equations, and the final result is given in Eq. (4-B-8).

$$V_{OUT3} = -\frac{R_4}{R_3}V_3 \tag{4-B-5}$$

$$V_{OUT1} = -\frac{R_4}{R_1}V_1 \tag{4-B-6}$$

$$V_{OUT2} = -\frac{R_4}{R_2}V_2 \tag{4-B-7}$$

$$V_{OUT} = -\left(\frac{R_4}{R_1}V_1 + \frac{R_4}{R_2}V_2 + \frac{R_4}{R_3}V_3\right) \tag{4-B-8}$$

New Words

loop [lu:p] *n.* 环，回路
influence [′influəns] *vt.* 影响，改变
lead [li:d] *n.* 导线
algebraic [ˌældʒi′breiik] *adj.* 代数的
manipulation [mə, nipju′leiʃən] *n.* 处理，操作
yield [ji:ld] *vt.* 出产，生产
parameter [pə′ræmitə] *n.* 参数，参量
accomplish [ə′kʌmpliʃ] *vt.* 完成，达到，实现
adjust [ə′dʒʌst] *vt.* 调整，调节，校准
assumption [ə′sʌmpʃən] *n.* 假定，设想
virtual [′və:tʃuəl] *adj.* 虚的
superposition [ˌsju:pəpə′ziʃən] *n.* 重叠，重合，叠加
calculate [′kælkjuleit] *vt.* 计算，考虑
reject [ri′dʒekt] *vt.* 拒绝，抵制，抑制
strip [strip] *vt.* 剥，剥去
derivative [di′rivətiv] *n.* 导数，导出物
initially [i′niʃəli] *adv.* 最初，开头
integrator [′intigreitə] *n.* 积分器
differentiator [ˌdifə′renʃieitə] *n.* 微分器，区分者

Phrases

Non-inverting Op-amp　非反向运放
stray capacitance　寄生电容
Kirchoff's law　基尔霍夫定律
voltage divider　分压器（电路）
voltage follower　电压跟随器
gain resistor　增益电阻
impedance level　阻抗水平
current drain　漏电流
stray capacitance　寄生电容
Inverting Op-amp　反相运放
virtual ground　虚地

Notes

1. In its most common use, the op-amp's output voltage is controlled by feeding a fraction of the output signal back to the *inverting input*, which provides negative feedback to the amplifier.

在最常见的应用当中，运放通过将一部分输出信号反送回其反相输入端来控制输出信号，这就生成了放大器的负反馈。

2. The non-inverting op-amp has the input signal connected to its non-inverting input, thus its input source sees an infinite impedance.

非反相运放的输入信号与其非反相输入端相接，因此从输入端看去阻抗为无穷大。

3. The gain is adjusted by varying the ratio of the resistors. The actual resistor values are determined by the impedance levels that the designer wants to establish.

通过改变电阻的比值可以调节增益的大小。实际的阻值是由设计者想要实现的阻抗水平来决定的。

4. One assumption made is that the input offset voltage is zero, so the feedback keeps inverting the input of the op-amp at a virtual ground (not actual ground but acting like ground).

我们假设输入失调电压为零，因此反馈环将运放输入端反相削弱并持续保持在一个虚地（并非真正的地，但功能与地相同）。

5. The impedance levels of 10 kΩ or 100 kΩ determine the current drain, the effect of stray capacitance, and a few other points.

10 kΩ或 100 kΩ的阻抗水平决定了由寄生电容效应产生的漏电流和一些其他点的值。

Exercises

[EX.1] Discussion.

1. Could you construct an Average Op-amp using what we have learnt so far?
2. How did op-amp come to use?
3. Can op-amp do other operation other than add, subtract, average?

[EX.2] Translate the following passages into Chinese.

1. Op-amps may be used to separate or decouple one circuit from another.
2. A series of op-amp circuits may be cascaded together to modify an input signal without significant attenuation.

3. The non-inverting op-amp is also known as a voltage follower with gain, or simply voltage follower.

4. The inverting op-amp is also known simply as the inverter.

5. The differential input amplifier is also known as differential amplifier, or subtractor.

6. The feedback resistor is of particular importance if the op-amp selected is a current-feedback type.

7. Unity gain circuits are used as electrical buffers to isolate circuits or devices from one another and prevent undesired interaction.

8. Today's modern differential input amplifier is used as an inverting amplifier by grounding the non-inverting input and applying the input signal to the inverting input terminal.

9. If a capacitor is used as the feedback element in the inverting amplifier, the result is an integrator.

10. In practical, an integrator often has a function switch. It operates as an integrator if it is switched to INTEGRATE mode, while discharges the capacitor and operates as an inverter if it is switched to RESET mode.

[EX.3] Translate the following passages into English.

1. 现代运算放大器是一种固态、高增益、直流电压放大器。
2. 运放可用于多种组态中来实现对电压电流信号的数学运算。
3. 在闭环组态下，反相输入端的电位总要被驱动到同相输入端的电位，即参考输入端电位。
4. 由于这种负反馈连接不需要差分输入，所以它曾是模拟计算机时代最为典型的应用。
5. 在反相放大器中，常在非反相输入端和地之间插入一个电阻（这样两个输入端就会看到一样的电阻值），以减少由偏移电流带来的不同的压降从而产生的输入失调电压，还可以减少一些运放中的失真。
6. 非反相运放的输入信号接在其非反相输入端，因此从其输入源端看去为无限阻抗。
7. 因为差分输入放大器只放大输入信号的差分部分，所以它会拒绝输入信号的共模部分。
8. 电流反馈运放的稳定性完全取决于所选用反馈电阻的阻值，设计者应该使用数据手册中该器件对应的推荐阻值。
9. 将一个电容作为反相放大器的输入元件可以产生出一个微分电路。
10. 另一种运放的典型组态为正反馈，其中输出信号的一部分被送回到非反相输入端。

[EX.4] Fill out the spaces after the record.

Op-amps are often used with__1__loops. A negative feedback is one that feeds a fraction of__2__signal back to the__3__input. In a non-inverting op-amp, the input signal is connected to the__4__input. When the resistor between the non-inverting input and output is zero, the op-amp becomes a voltage__5__. __6__feedback doesn't require a differential input, thus is used quite often. An inverter has its__7__input connected to the ground. An adder has more input connected to its__8__input. In an adder, current in the feedback loop is the algebraic__9__of the current due to each input. When the output signal is connected to the non-inverting input, it's called __10__feedback.

Section C　专业英语常见动词、动词形态、名词的翻译

1. 专业英语中的常见动词翻译

专业英语中动词使用的套路相对固定。在一篇专业文章中，出现得最多的动词，其意义无非是

表示、说明/证明、得出结论、构成/组成、完成、提出等。在此，为了方便读者，我们把这些常用动词的英汉翻译对应列举出来，以利查阅参考。

（1）利用、使用、应用

use, make use of, employ, exploit, utilize, apply to

（2）组成、构成、包括

form, make up, compose, constitute, include, comprise, consist of, incorporate

（3）完成、完结、完工

complete, accomplish, fulfill, finish, be ready, end, be over, finish, complete a project, finish doing sth., get through

（4）表明、说明、表示、证明、证实

show, indicate, denote, signify, explain, illustrate, interpret, express, demonstrate, represent, prove, confirm, verify, support

（5）检查、检验

examine, test, inspect, judge

（6）提出、提议、建议

put forward, suggest/propose a theory that ..., advance, formulate, propose, suggest, move, recommend

（7）获得、得到、得出结论

win, acclaim, earn, achieve, acquire, get, obtain, gain, reach, draw, form, make a conclusion, come to a conclusion, arrive at a conclusion, conclude

（8）分为、划分、区分

divide, fall into, differentiate, determine, classify, distinguish

（9）限、局限、限制、限于

confine, limit, restrict

（10）算、计算、推算、换算、数

calculate, compute, convert, count

（11）发明、发现、创造、创立

invent, develop, find, discover, create, make, found, establish

（12）解释、描述、阐述、论述

explain, interpret, describe, expound, elaborate, set forth, make an exposition of

（13）考虑、认为

consider, deem, hold, maintain, take ... into account, think

（14）改变、转变

change, alter, vary, transform, convert

（15）扩大、放大

extend, expand, enlarge

（16）减小、减少、缩短

reduce, contract, decrease, cut, shorten

（17）代替、代入

replace, substitute for, take the place of, instead, substitute, insert, put

以上所列举的，都是专业英语中最常出现的“高频”动词。掌握它们的英汉互译，对专业英语的阅读和写作都大有帮助。另一方面，英文中动词有所谓“态”的变化，这是在处理专业英语动词翻译时需要留意的地方。此外，动词所含有的专业含义，也是我们需要考虑的方面。

2. 专业英语中动词形态的翻译

（1）动词时态的翻译

英语和汉语在很多情况下的时态，从字面上看并不一致，这是这两种语言不同的特点所决定的。但是它们表达的概念、条理和逻辑的要求是一致的，词与词项、句子各部分的主题关系也是基本一致的。英译汉时，为了符合汉语的表达习惯，需要进行时态的转换。科技英语翻译中常见的时态转换有如下几种。

① 英语的一般现在时译为汉语的将来时、进行时或过去时。

The cancer reverses completely thanks to early treatment.

早期治疗癌症是可以完全治愈的。（将来时）

The electronic computers play an important part in science and technology.

电子计算机在科学和技术方面起着重要的作用。（进行时）

These substances further speed up the decay process.

这些物质进一步加速了衰变过程。（过去时）

② 英语动词的进行时可译成汉语的将来时。

Knowing severe winter is coming would enable squirrel to store plenty of food.

松鼠预知严冬将至而储藏大量的食物。

③ 英语动词的完成时翻译成汉语的过去时。

The sales of industrial electronic products have multiplied five times.

工业电子产品的销售值增长了 5 倍。

（2）非限定性动词的翻译

专业英语中广泛使用的非限定性动词（即分词、不定式和动名词）在句子中扮演着各种成分。它的用法在上一单元已有详尽的论述。在阅读翻译时，要根据它所具有的语法意义和在科技英语中暗含的科技含义转换为适当的汉语词汇意义，必要时还要进行词的增补。

① 汉语中没有限定性动词和非限定性动词的分类。

非限定性动词相当于汉语中的动词，而且英语语言主要依仗形态表意。汉语主要依仗词汇表意，英译汉时为了准确表达出它的科技含义，最为常见的是对词的增补和意译。例如：

- 增补英语中省略的词

cycling（周期变化），seeding（引晶技术），tunneling（遂道效应），modulated voltage（已调制电压）

- 增加关联词语

Heated, water will change to vapor.

如水受热，就会变为水蒸气。

- 修饰加词，语气连贯

Heat from the sun stirs up the atmosphere, generating winds.

太阳发出的热能搅动大气，于是产生了风。

② 当非限定性动词的概念难以用汉语的动词表达，或者这样的表达不符合汉语的表达习惯时，可将其翻译成汉语的其他词类。

Momentum is defined as the product of the velocity and a quantity of the body.

动量的定义是速度和物体质量的乘积。（转换成名词）

In this and the following sections, we will employ Ideal Op Amp analysis continuously to help you understand the basic principles and dig into the properties of the real devices later by yourselves and finally investigate circuits utilizing practical operational amplifiers.

在本节和后面的章节中，我们将持续使用理想运放分析法来帮助读者理解一些基本原理，以便读者以后能够自己发掘实际器件的特性，直至最终能够分析使用实际运放的电路。（译成形容词）

（3）动词语态的翻译

正如上一单元所提及，被动语态在专业英语中随处可见。汉语中的被动语态，通常通过“把”或“被”等词来体现。但它的使用范围远远小于英语中被动语态的使用范围，因此英语中的被动语态在很多情况下都翻译成主动结构。对于英语原文的被动结构，一般采取下列的方法，翻译成汉语的主动句。

英语原文的被动结构翻译成汉语的主动结构又可以进一步分为几种不同的情况。

① 英语原文中的主语在译文中仍做主语。在采用此方法时，我们往往在译文中使用了“加以”、“经过”、“用……来”等词来体现原文中的被动含义。例如：

Other questions will be discussed briefly.

其他问题将简单地加以讨论。

In its most common use, the op-amp's output voltage is controlled by feeding a fraction of the output signal back to the *inverting input*, which provides negative feedback to the amplifier.

在最常见的应用当中，运放通过将一部分输出信号反送回其反相输入端来控制输出信号，这就生成了放大器的负反馈。

Nuclear power's danger to health, safety, and even life itself can be summed up in one word: radiation.

核能对健康、安全甚至对生命本身构成的危险可以用一个词——辐射来概括。

② 将英语原文中的主语翻译为宾语，同时增补泛指性的词语（人们、大家等）做主语。例如：

It could be argued that the radio performs this service as well, but on television everything is much more living, much more real.

可能有人会指出，无线电广播同样也能做到这一点，但还是电视屏幕上的节目要生动、真实得多。

It was found that the application of negative feedback around a high gain DC amplifier would produce a circuit with a precise gain characteristic that depended only on the feedback used.

人们发现在高增益直流放大器周围使用负反馈可以产生一种带有精确增益特性的电路，且该特性仅依赖于所用的反馈网络。

The gain is adjusted by varying the ratio of the resistors. The actual resistor values are determined by the impedance levels that the designer wants to establish.

通过改变电阻的比值可以调节增益的大小。实际的阻值是由设计者想要实现的阻抗水平来决定的。

另外，下列的结构也可以通过这一手段翻译：

It is asserted that …　有人主张……

It is believed that …　有人认为……

It is generally considered that …　大家（一般人）认为……

It is well known that …　大家知道（众所周知）……

It will be said … 有人会说……

It was told that … 有人曾经说……

③ 将英语原文中的 by、in、for 等做状语的介词短语翻译成译文的主语，在此情况下，英语原文中的主语一般被翻译成宾语。例如：

A right kind of fuel is needed for an atomic reactor.

原子反应堆需要一种合适的燃料。

By the end of the war, 800 people had been saved by the organization, but at a cost of 200 Belgian and French lives.

大战结束时, 这个组织拯救了 800 人，但那是以 200 多比利时人和法国人的生命为代价的。

3. 专业英语中名词的翻译

专业英语中大量的名词均为专业词汇。此部分内容在第 2 单元就已提及，其翻译原则是准确性和实用性。准确性即应确切弄清原专业名词的真正含义，使译文与原文完全等值等价，表达同一概念；实用性即应保证译文通俗易懂，规范实用。具体的翻译方法有下列几种。

（1）意译

意译就是根据专业术语的技术含义翻译成汉语中和它完全对等的名词，此种译法在专业术语的翻译中起着最主要的作用。它具有概念明确，易懂易记的特点。例如：

amplifier 放大器，扩音器；loop 环，回路；parameter 参数，参量；register 寄存器；

pin 引脚；semiconductor 半导体；simulator 模拟器；module 模块

（2）音译

顾名思义，音译就是按原词的英语发音译成对应的汉字。在英语科技术语中，物理量的单位、一些新材料的名称、英文首字母缩写词及一些新术语的译名，一般采用音译法。例如：

hacker 黑客；clone 克隆；pint 品脱；gamma 伽马

（3）形译

在科技术语中，有一些术语常由大写字母和名词构成（中间加连字符），其中的大写字母表示事物的几何形状；还有一些术语是由表示事物形状的单词和另一名词构成的。对这些术语，翻译时也可通过具体形象来表达。这种译法既非意译，又非音译，可称为形译。例如：

T-coupling 三通接头；V-bridge V 式电桥；zigzag line 锯齿形曲线；cross joint 四通接头

第 2 单元中给读者介绍的大量英语专业词汇构成的各类词缀，也是帮助专业英语名词翻译的良好工具。