电子信息科学
专业英语教程

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哈尔滨地图出版社

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内 容 简 介

本书选自英文原版教材、书刊或网上文章，内容围绕电子信息科学、通信及计算机等前沿领域的相关知识，按知识结构分为四个部分，涉及电子电路、EDA 设计、微处理器、计算机网络、多媒体技术、通信技术、信号与图像处理、模式识别与人工智能、生物特征识别等电子信息科学的专业知识，内容广泛，选材新颖。本书可使读者熟悉和掌握一定的专业英语词汇和术语，了解科技文献的表达特点，提高阅读和理解专业英语文献的能力和速度，培养英语写作和翻译技巧，开阔专业视野。

本书可作为高等院校电子信息科学、通信工程、电子信息工程、计算机科学、自动化技术等相关专业研究生、本科生的专业英语教材，也可作为相关领域专业人员提高英语水平的阅读参考书。本书同样适合参加四、六级和研究生入学考试的学生熟悉电子信息类相关文献和锻炼阅读能力。

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前　言

本书根据国家教育部高等教育本科教学《专业英语阅读》大纲的要求，为电子信息类研究生、大学本科三、四年级学生提高本专业及相关专业英语阅读水平而编写。

本书结合电子信息技术发展的特点，力求反映信息科学相关专业最新技术发展和主流技术，使读者在了解和感悟专业知识与技术发展的同时，融会贯通所学专业知识，全面了解专业涉及技术，以引导和提高读者学习、研究及开发设计的兴趣。

本书选材新题、内容丰富，选材立足专业性、实用性，兼顾发展热点和本专业主流技术，课文内容取自英语原文教材、网上或书刊中的文章和章节，经编写而写成，涉及到电子信息类专业的电子电路、EDA设计、微处理器设计、计算机网络、多媒体技术、移动通信、光纤通信等知识，还包括模式识别与人工智能、信号与信息处理、数字图像处理、生物特征识别、信息安全、GPS、3G通信等发展热点问题。所选材料突出技术内容的正确性、完整性，兼顾读者的接受能力，按知识结构体系组织编排，由浅入深。

书中覆盖了大量的电子、计算机、通信及电器自动化等方面的专业词汇和术语；力求脱离大学英语的教学模式，最大程度接近专业英语和专业文献的表达形式，通过学习，读者可熟悉和掌握相关领域科技英语句法特点和常用表达方式。另外，在附录中还介绍了一些科技论文写作和学术交流中常用的英语表达知识，力求学以致用。这样，教师可根据学生的接受能力，结合学时安排合理选用，同时配合灵活多样的课堂教学和课后练习，多方位地培养学生专业用语的运用能力。

本书由多年从事《专业英语阅读》教学的教师蒋爱平主编。其中第一部分由汪国强编写，第二部分由蒋爱平编写，第三部分由鲍东星编写，第四部分由王英丽编写。

主审叶红安对本书进行了认真地审阅，并提出了许多宝贵意见。

限于编者水平，如有不妥和错误之处，恳请读者批评指正。

编　者

2006年1月

目　录

Part 1 Foundation of Electronics

Unit 1 Foundations

1. 1 Voltage and Current

There are two quantities that we like to keep track of in electronic circuits: voltage and current. These are usually changing with time; otherwise nothing interesting is happening.

Voltage (symbol: V, or sometimes E). The voltage between two points is the cost in energy (work done) required to move a unit of positive charge from the more negative point (lower potential) to the more positive point (higher potential). Equivalently, it is the energy released when a unit charge moves "downhill" from the higher potential to the lower. Voltage is also called potential difference or electro - motive force (EMF). The unit of measure is the volt, with voltages usually expressed in volts (V), kilovolts (1 kV = 10^3 V), millivolts (1 mV = 10^{-3} V), or microvolts (1 μV = 10^{-6} V). A joule of work is needed to move a coulomb of charge through a potential difference of one volt(The coulomb is the unit of electriccharge, and it equals the charge of 6 $\times 10^{18}$ electrons, approximately) . For reasons that will become clear later, the opportunities to talk about nanovolts (1 nV = 10^{-9} V) and megavolts (1 MV = 10^6 V) are rare.

Current (symbol: I). Current is the rate of flow of electric charge past a point. The unit of measure is the ampere, or amp, with currents usually expressed in amperes(A), milliamperes (1 mA = 10^{-3} A), micro-amperes (1 μA = 10^{-6} A), nanoamperes (1 nA = 10^{-9} A), or occasionally picoamperes (1 pA = 10^{-12} A). A current of one ampere equals a flow of one coulomb of charge per second. By convention, current in a circuit is considered to flow from a more positive point to a more negative point, even though the actual electron flow is in the opposite direction.

Important: Always refer to voltage between two points or across two points in a circuit. Always refer to current through a device or connection in a circuit.

To say something like "the voltage through a resistor …" is nonsense, or worse. However, we do frequently speak of the voltage at a point in a circuit. This is always understood to mean voltage between that point and "ground", a common point in the circuit that everyone seems to know about. Soon you will, too.

We generate voltages by doing work on charges in devices such as batteries (electrochemical), generators (magnetic forces), solar cells (photovoltaic conversion of the energy of photons), etc. We get currents by placing voltages across things.

At this point you may well wonder how to "see" voltages and currents. The single most useful electronic instrument is the oscilloscope, which allows you to look at voltages (or occasionally currents) in a circuit as a function of time. We will deal with oscilloscopes, and alsovoltmeters, when we discuss signals shortly.

In real circuits we connect things together with wires, metallic conductors, each of which has the same voltage on it everywhere (with respect to ground, say) (In the domain of high frequencies or low impedances, that isn't strictly true, and we will have more to say about this later. For now, it's a good approximation). We mention this now so that you will realize that an actual circuit doesn't have to look like its schematic diagram, because wires can be rearranged.

Here are some simple rules about voltage and current:

1. The sum of the currents into a point in a circuit equals the sum of the currents out (conservation of charge). This is sometimes called Kirchhoff's current law. Engineers like to refer to such a point as a node. From this, we get the following: For a series circuit (a bunch of two-terminal things all connected end-to-end) the current is the same everywhere.

2. Things hooked in parallel have the same voltage across them. Restated, the sum of the "voltage drops" from A to B via one path through a circuit equals the sum by any other route equals the voltage between A and B. Sometimes this is stated as follows: The sum of the voltage drops around any closed circuit is zero. This is Kirchhoff's voltage law.

3. The power (work per unit time) consumed by a circuit device is $P = VI$. This is simply(work/charge) ×(charge/ time). For V in volts and I in amps, P comes out in watts. Watts are joules per second (1 W =1 J/s).

Power goes into heat (usually), or sometimes mechanical work (motors), radiated energy (lamps, transmitters), or stored energy (batteries, capacitors). Managing the heat load in a complicated system (e. g. , a computer, in which many kilowatts of electrical energy are converted to heat, with the energetically insignificant by-product of a few pages of computational results) can be a crucial part of the system design.

Soon, when we deal with periodically varying voltages and currents, we will have to generalize the simple equation $P = VI$ to deal with average power, but it's correct as a statement of instantaneous power just as it stands.

Incidentally, don't call current "amperage"; that's strictly bush-league. The same caution will apply to the term "ohmage" when we get to resistance in the next section.

PREFIXES

These prefixes are universally used to scale units in science and engineering.

Multiple	*Prefix*	*Symbol*
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{-3}	milli	m
10^{-6}	micro	μ

10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f

When abbreviating a unit with a prefix, the symbol for the unit follows the prefix without space. Be careful about upper-case and lower-case letters (especially m and M) in both prefix and unit: 1 mW is a milliwatt, or one-thousandth of a watt; 1 MHz is 1 million hertz. In general, units are spelled with lower-case letters, even when they are derived from proper names. The unit name is not capitalized when it is spelled out and used with a prefix, only when abbreviated. Thus: hertz and kilohertz, but Hz and kHz; watt, milliwatt, and megawatt, but W, mW, and MW.

1.2 Resistor

This is a long and interesting story. It is the heart of electronics. Crudely speaking, the name of the game is to make and use gadgets that have interesting and useful I-versus-V characteristics. Resistors (I simply proportional to V), capacitors (I proportional to rate of change of V), diodes (I flows in only one direction), thermistors (temperature-dependent resistor), photoresistors (light-dependent resistor), strain gauges (strain-dependent resistor), etc., are examples. We will gradually get into some of these exotic devices; for now, we will start with the most mundane (and most widely used) circuit element, the resistor.

Resistance and resistors

It is an interesting fact that the current through a metallic conductor (or other partially conducting material) is proportional to the voltage across it (In the case of wire conductors used in circuits, we usually choose a thick enough gauge of wire so that these "voltage drops" will be negligible). This is by no means a universal law for all objects. For instance, the current through a neon bulb is a highly nonlinear function of the applied voltage (It is zero up to a critical voltage, at which point it rises dramatically). The same goes for a variety of interesting special devices - diodes, transistors, light bulbs, etc. A resistor is made out of some conducting stuff (carbon, or a thin metal or carbon film, or wire of poor conductivity), with a wire coming out each end. It is characterized by its resistance:

$$R = V/I$$

R is in ohms for V in volts and I in amps. This is known as Ohm's law. Typical resistors of the most frequently used type (carbon composition) come in values from 1 ohm (1 Ω) to about 22 megohms (22 MΩ). Resistors are also characterized by how much power they can safely dissipate (the most commonly used ones are rated at 1/4 watt) and by other parameters such as tolerance (accuracy), temperature coefficient, noise, voltage coefficient, stability with time, inductance, etc.

Roughly speaking, resistors are used to convert a voltage to a current, and vice versa. This may sound awfully trite, but you will soon see what we mean.

Some more home-grown philosophy: There is a tendency among beginners to want to compute resistor values and other circuit component values to many significant places, and the availability of inexpensive calculators has only made matters worse. There are two reasons you should try to avoid falling into this habit: (a) the components themselves are of finite precision (typical resistors are 5; the parameters that characterize transistors, say, frequently are known only to a factor of two); (b) one mark of a good circuit design is insensitivity of the finished circuit to precise values of the components (there are exceptions, of course). You'll also learn circuit intuition more quickly if you get into the habit of doing approximate calculations in your head, rather than watching meaningless numbers pop up on a calculator display.

In trying to develop intuition about resistance, some people find it helpful to think about conductance, $G = 1/R$. The current through a device of conductance G bridging a voltage V is then given by $I = GV$ (Ohm's law). A small resistance is a large conductance, with correspondingly large current under the influence of an applied voltage.

Viewed in this light, the formula for parallel resistors is obvious: When several resistors or conducting paths are connected across the same voltage, the total current is the sum of the individual currents. Therefore the net conductance is simply the sum of the individual conductances, $G = G_1 + G_2 + G_3 + \cdots$, which is the same as the formula for parallel resistors derived earlier.

Engineers are fond of defining reciprocal units, and they have designated the unit of conductance the Siemens ($S = 1/\Omega$), also known as the mho (that's ohm spelled backward, given the symbol U). Although the concept of conductance is helpful in developing intuition, it is not used widely; most people prefer to talk about resistance instead.

Resistors

Resistors are truly ubiquitous. There are almost as many types as there are applications. Resistors are used in amplifiers as loads for active devices, in bias networks, and as feedback elements. In combination with capacitors they establish time constants and act as filters. They are used to set operating currents and signal levels. Resistors are used in power circuits to reduce voltages by dissipating power, to measure currents, and to discharge capacitors after power is removed. They are used in precision circuits to establish currents, to provide accurate voltage ratios, and to set precise gain values. In logic circuits they act as bus and line terminators and as "pull-up" and "pull-down" resistors. In high-voltage circuits they are used to measure voltages and to equalize leakage currents among diodes or capacitors connectedin series. In radiofrequency circuits they are even used as coil forms for inductors.

Resistors are available with resistances from 0.01 ohm through 10^{12} ohms, standard power ratings from 1/8 watt through 250 watts, and accuracies from 0.005% through 20%. Resistors can be made from carbon-composition moldings, from metal films, from wire wound on a form, or from semiconductor elements similar to field-effect transistors (FETs). But by far the most familiar resistor is the 1/4 or 1/2 watt carbon-composition resistor. These are available in a standard set of values ranging from 1 ohm to 100 megohms with twice as many values available for the 5% tolerance as for the 10% types. We prefer the Allen - Bradley type AB (1/4 watt, 5%) resistor for general use because of its clear marking, secure lead seating, and stable properties.

Resistors are so easy to use that they're often taken for granted. They're not perfect, though, and it is worthwhile to look at some of their defects. The popular 5% composition type, in particular, although fine for nearly all noncritical circuit applications, is not stable enough for precision applications. You should know about its limitations so that you won't be surprised someday. Its principal defects are variations in resistance with temperature, voltage, time, and humidity. Other defects may relate to inductance (which may be serious at high frequencies), the development of thermal hot spots in power applications, or electrical noise generation in low - noise amplifiers.

1.3 Signals

Sinusoidal signals

Sinusoidal signals are the most popular signals around; they're what you get out of the wall plug. If someone says something like "take a 10 microvolt signal at 1 megahertz", he means a sine wave. Mathematically, what you have is a voltage described by

$$V = A\sin 2\pi ft$$

where A is called the amplitude, and f is the frequency in cycles per second, or hertz. A sine wave looks like the wave shown in Figure 1.1.1. Sometimes it is important to know the value of the signal at some arbitrary time $t = 0$, in which case you may see a phase φ in the expression:

$$V = A\sin(2\pi ft + \varphi)$$

The other variation on this simple theme is the use of angular frequency, which looks like this:

$$V = A\sin \omega t$$

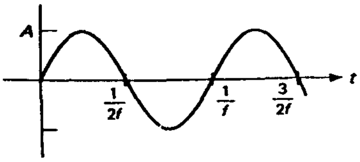

Figure 1.1.1 Sine wave of amplitude A and frequency f

Here, ω is the angular frequency in radians per second. Just remember the important relation $\omega = 2\pi f$ and you won't go wrong.

The great merit of sine waves (and the cause of their perennial popularity) is the fact that they are the solutions to certain linear differential equations that happen to describe many phenomena in nature as well as the properties of linear circuits. A linear circuit has the property that its output, when driven by the sum of two input signals, equals the sum of its individual outputs when driven by each input signal in turn; i. e., if $O(A)$ represents the output when driven by signal A, then a circuit is linear if $O(A + B) = O(A) + O(B)$. A linear circuit driven by a sine wave always responds with a sine wave although in general the phase and amplitude are changed. No other signal can make this statement. It is standard practice, in fact, to describe the behavior of a circuit by a "flat" frequency response, the way it alters the amplitude of an applied sine wave as a function of frequency. A high - fidelity amplifier, for instance, should be characterized by a "flat" frequency response over the range

20 Hz to 20 kHz at least.

The sine-wave frequencies you will usually deal with range from a few hertz to a few megahertz. Lower frequencies, down to 0.000 1 Hz or lower, can be generated with carefully built circuits, if needed. Higher frequencies, e.g., up to 2 000 MHz, can be generated, but they require special transmission-line techniques. Above that, you're dealing with microwaves, where conventional wired circuits with lumped circuit elements become impractical, and exotic waveguides or "striplines" are used instead.

Signal amplitudes and decibels

In addition to its amplitude, there are several other ways to characterize the magnitude of a sine wave or any other signal. You sometimes see it specified by peak-to-peak amplitude (pp amplitude), which is just what you would guess, namely, twice the amplitude. The other method is to give the root-mean-square amplitude (rms amplitude), which is $V_{rms} = (1/\sqrt{2})A = 0.707\ A$ (this is for sine waves only; the ratio of pp to rms will be different for other waveforms). Odd as it may seem, this is the usual method, because rms voltage is what's used to compute power. The voltage across the terminals of a wall socket (in the United States) is 117 volts rms, 60 Hz. The amplitude is 165 volts (330 volts pp).

Decibels

How do you compare the relative amplitudes of two signals? You could say, for instance, that signal X is twice as large as signal Y. That's fine, and useful for many purposes. But because we often deal with ratios as large as a million, it is easier to use a logarithmic measure, and for this we present the decibel (it's one-tenth as large as something called a bel, which no one ever uses). By definition, the ratio of two signals, in decibels, is

$$\mathrm{d}B = 20\ \log_{10}\frac{A_2}{A_1}$$

where A_1 and A_2 are the two signal amplitudes. So, for instance, one signal of twice the amplitude of another is $+6\mathrm{d}B$ relative to it, since $\log_{10}2 = 0.301\ 0$. A signal 10 times as large is $+20\ \mathrm{d}B$; a signal one-tenth as large is $-20\ \mathrm{d}B$. It is also useful to express the ratio of two signals in terms of power levels:

$$\mathrm{d}B = 10\log_{10}\frac{P_2}{P_1}$$

where P_1 and P_2 represent the power in the two signals. As long as the two signals have the same kind of waveform, e.g., sine waves, the two definitions give the same result. When comparing unlike waveforms, e.g., a sine wave versus "noise", the definition in terms of power (or the amplitude definition, with rms amplitudes substituted) must be used.

Although decibels are ordinarily used to specify the ratio of two signals, they are sometimes used as an absolute measure of amplitude. What is happening is that you are assuming some reference signal amplitude and expressing any other amplitude in decibels relative to it. There are several standard amplitudes (which are unstated, but understood) that are used in this way; the most common references are (a) d*B* V; 1 volt rms; (b) d*B*m; the voltage corresponding to 1 mW into some assumed load impedance, which for radiofrequencies is usually 50 ohms, but for audio is often 600 ohms (the corresponding 0d*B*m amplitudes, when loaded by those impedances, are then 0. 22 V rms and 0. 78V rms); and (c) the small noise voltage generated by a resistor at room temperature. In addition to these, there are reference amplitudes used for measurements in other fields. For instance, in acoustics, 0d*B* SPL is a wave whose rms pressure is 0. 000 2 μbar (a bar is 10^6 dynes per square Centimeter, approximately 1 atmosphere); in communications, levels can be stated in d*B*rnC (relative noise reference weighted in frequency by "curve C"). When stating amplitudes this way, it is best to be specific about the 0d*B* reference amplitude; say something like "an amplitude of 27 decibels relative to 1 volt rms" ,or abbreviate "27 d*B* re 1V rms" ,or define a term like "dBV".

1.4 Capacitor, Inductor and Transformer

Capacitor

A capacitor (the old – fashioned name was condenser) is a device that has two wires sticking out of it and has the property

$$Q = CV$$

A capacitor of C farads with V volts across its terminals has Q coulombs of stored charge on one plate, and $-Q$ on the other.

To a first approximation, capacitors are devices that might be considered simply frequency – dependent resistors. They allow you to make frequency – depended voltage dividers, for instance For some applications (bypass, coupling) this is almost all you need to know, but for other applications (filtering, energy storage, resonant circuits) a deeper understanding is needed. For example, capacitors cannot dissipate power, even though current can flow through them, because the voltage and current are 90 out of phase.

Taking the derivative of the defining equation above, you get

$$I = C\frac{dV}{dt}$$

So a capacitor is more complicated than a resistor; the current is not simply proportional to the voltage, but rather to the rate of change of voltage. If you change the voltage across a farad by 1 volt per second, you are supplying an amp. Conversely, if you supply an amp, its voltage changes by 1 volt per second. A farad is very large, and you usually deal in microfarads (μF) or picofarads (pF). (To make matters confusing to the uninitiated, the units are often omitted on capacitor values specified in schematic diagrams. You have to figure it out from the context.) For instance, if you supply a current of 1mA to 1μF, the voltage will rise at 1 000 volts per second. A 10ms pulse of this current will increase the

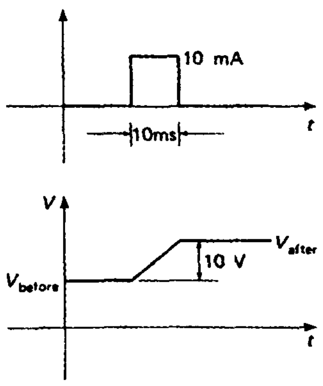

Figure 1. 1. 2 The voltage across a capacitor changes when a current flows through it

voltage across the capacitor by 10 volts. (Fig. 1. 1. 2).

Capacitors come in an amazing variety of shapes and sizes; with time, you will come to recognize their more common incarnations. The basic construction is simply two conductors near each other (but not touching); in fact, the simplest capacitors are just that. For greater capacitance, you need more area and closer spacing; the usual approach is to plate some conductor onto a thin insulating material (called a dielectric), for instance, aluminized Mylar film rolled up into a small cylindrical configuration. Other popular types are thin ceramic wafers (disc ceramics), metal foils with oxide insulators (electrolytics), and metallized mica. Each of these types has unique properties. In general, ceramic and Mylar types are used for most noncritical circuit applications; tantalum capacitors are used where greater capacitance is needed, and electrolytics are used for power-supply filtering.

Capacitors in parallel and series

The capacitance of several capacitors in parallel is the sum of their individual capacitances. This is easy to see: Put voltage V across the parallel combination; then

$$\begin{aligned} C_{total}V &= Q_{total} = Q_1 + Q_2 + Q_3 + \cdots \\ &= C_1V + C_2V + C_3V + \cdots \\ &= (C_1 + C_2 + C_3 + \cdots)V \end{aligned}$$

or

$$C_{total} = C_1 + C_2 + C_3 + \cdots$$

For capacitors in series, the formula is like that for resistors in parallel:

$$C_{total} = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \cdots}$$

or (two capacitors only)

$$C_{total} = \frac{C_1C_2}{C_1 + C_2}$$

The current that flows in a capacitor during charging ($I = CdV/dt$) has some unusual features. Unlike resistive current, it's not proportional to voltage, but rather to the rate of change (the "time derivative") of voltage. Furthermore, unlike the situation in a resistor, the power (V times I) associated with capacitive current is not turned into heat, but is stored as energy in the capacitor's internal electric field. You get all that energy back when you discharge the capacitor.

Inductors

If you understand capacitors, you won't have any trouble with inductors. They're closely related to capacitors; the rate of current change in an inductor depends on the voltage applied across it, whereas the rate of voltage change in a capacitor depends on the current through it. The defining equation for an inductor is

$$V = L\frac{\mathrm{d}I}{\mathrm{d}t}$$

where L is called the inductance and is measured in henrys (or mH, μH, etc). Putting a voltage across an inductor causes the current to rise as a ramp (for a capacitor, supplying a constant current causes the voltage to rise as a ramp); 1 volt across 1 henry produces a current that increases at 1 amp per second.

As with capacitive current, inductive current is not simply proportional to voltage. Furthermore, unlike the situation in a resistor, the power associated with inductive current (V times I) is not turned into heat, but is stored as energy in the inductor's magnetic field. You get all that energy back when you interrupt the inductor's current.

The symbol for an inductor looks like a coil of wire; that's because, in its simplest form, that's all it is. Variations include coils wound on various core materials, the most popular being iron (or iron alloys, laminations, or powder) and ferrite, a black, nonconductive, brittle magnetic material. These are all ploys to multiply the inductance of a given coil by the "permeability" of the core material. The core may be in the shape of a rod, a toroid (doughnut), or even more bizarre shapes, such as a "pot core" (which has to be seen to be understood; the best description we can think of is a doughnut mold split horizontally in half, if doughnuts were made in molds).

Inductors find heavy use in radio-frequency (RF) circuits, serving as RF "chokes" and as parts of tuned circuits. A pair of closely coupled inductors forms the interesting object known as a transformer. We will talk briefly about them in the next section.

Transformers

A transformer is a device consisting of two closely coupled coils (called primary and secondary). An ac voltage applied to the primary appears across the secondary, with a voltage multiplication proportional to the turns ratio of the transformer and a current multiplication inversely proportional to the turns ratio. Power is conserved. Figure 1. 1. 3 shows the circuit symbol for a laminated-core transformer (the kind used for 60 Hz ac power conversion).

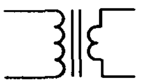

Figure 1. 1. 3 Transformer

Transformers are quite efficient (output power is very nearly equal to input power); thus, a step-up transformer gives higher voltage at lower current. Jumping ahead for a moment, a transformer of turns ratio n increases the impedance by n^2. There is very little primary current if the secondary is unloaded.

Transformers serve two important functions in electronic instruments: They change the ac line voltage to a useful (usually lower) value that can be used by the circuit, and they "isolate" the electronic device from actual connection to the power line, because the windings of a transformer are electrically insulated from each other. Power transformers(meant for use from the 110 V power line) come in an enormous variety of secondary voltages and currents: outputs as low as 1 volt or so up to several thousand volts, current ratings from a few milliamps to hundreds of amps. Typical transformers for use in electronic instruments might have secondary voltages from 10 to 50 volts, with current ratings of 0. 1 to 5 amps or so.

Transformers for use at audiofrequencies and radiofrequencies are also available. At radiofrequencies you sometimes use tuned transformers, if only a narrow range of frequencies is present. In general, transformers for use at high frequencies must use special core materials or construction to minimize core losses, whereas low - frequency transformers (e. g. , power transformers) are burdened instead by large and heavy cores. The two kinds of transformers are in general not interchangeable.

Impedance And Reactance

Circuits with capacitors and inductors are more complicated than the resistive circuits we talked about earlier, in that their behavior depends on frequency: A "voltage divider" containing a capacitor or inductor will have a frequency - dependent division ratio. In addition, circuits containing these components (known collectively as reactive components) "corrupt"input waveforms such as square waves, as we just saw.

However, both capacitors and inductors are linear devices, meaning that the amplitude of the output waveform, whatever its shape, increases exactly in proportion to the input waveform's amplitude. This linearity has many consequences, the most important of which is probably the following: The output of a linear circuit, driven with a sine wave at some frequency f , is itself a sine wave at the same frequency (with, at most, changed amplitude and phase).

Because of this remarkable property of circuits containing resistors, capacitors, and inductors (and, later, linear amplifiers), it is particularly convenient to analyze any such circuit by asking how the output voltage(amplitude and phase) depends on the input voltage, for sine - wave input at a single frequency, even though this may not be the intended use. A graph of the resulting frequency response, in which the ratio of output to input is plotted for each sine - wave frequency, is useful for thinking about many kinds of waveforms. As an example, a certain "boom - box" loudspeaker might have the frequency response shown in Figure 1. 1. 4, where the "output" in this case is of course sound pressure, not voltage. It is desirable for a speaker to have a "flat" response, meaning that the graph of sound pressure versus frequency is constant over the band of audible frequencies. In this case the speaker's deficiencies can be corrected by introducing a passive filter with the inverse response (as shown) into the amplifiers of the radio.

As we will see, it is possible to generalize Ohm's law, replacing the word "resistance" with "impedance" , in order to describe any circuit containing these linear passive devices (resistors, capacitors, and inductors). You could think of the subject of impedance and reactance as Ohm's law for circuits that include capacitors and inductors. Some important

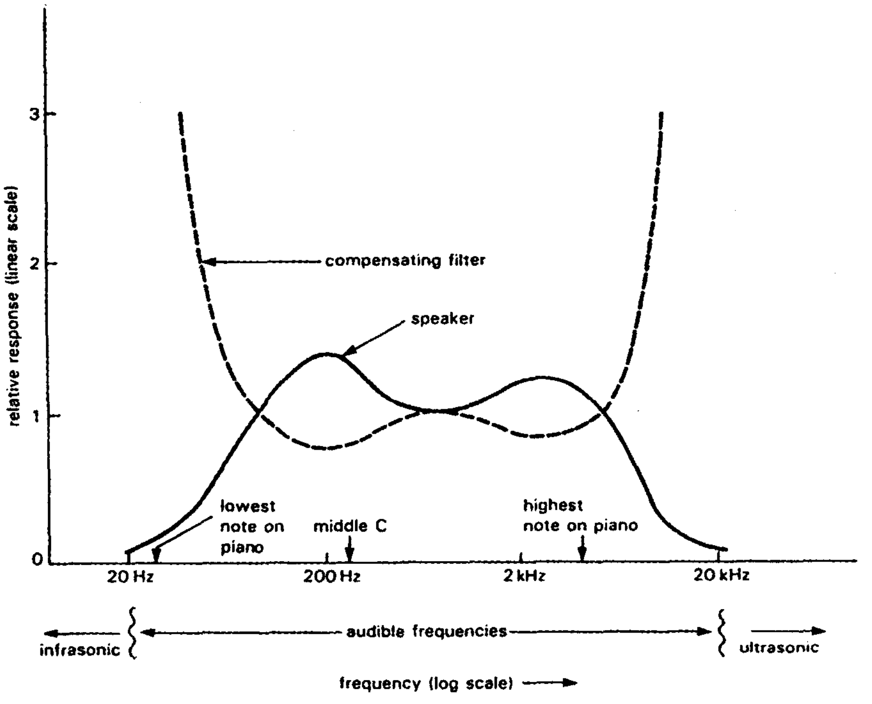

Figure 1. 1. 4 Example of frequency analysis: "boom box" loudspeaker equalization

terminology: Impedance is the "generalized resistance"; inductors and capacitors have reactance (they are "reactive"); resistors have resistance (they are "resistive"). In other words, impedance = resistance + reactance (more about this later). However, you'll see statements like "the impedance of the capacitor at this frequency is ··· " The reason you don't have to use the word "reactance" in such a case is that impedance covers everything. In fact, you frequently use the word "impedance" even when you know it's a resistance you're talking about; you say "the source impedance" or "the output impedance" when you mean the Thevenin equivalent resistance of some source. The same holds for "input impedance."

In all that follows, we will be talking about circuits driven by sine waves at a single frequency. Analysis of circuits driven by complicated waveforms is more elaborate, involving the methods we used earlier (differential equations) or decomposition of the waveform into sine waves (Fourier analysis). Fortunately, these methods are seldom necessary.

Electrical Networks

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