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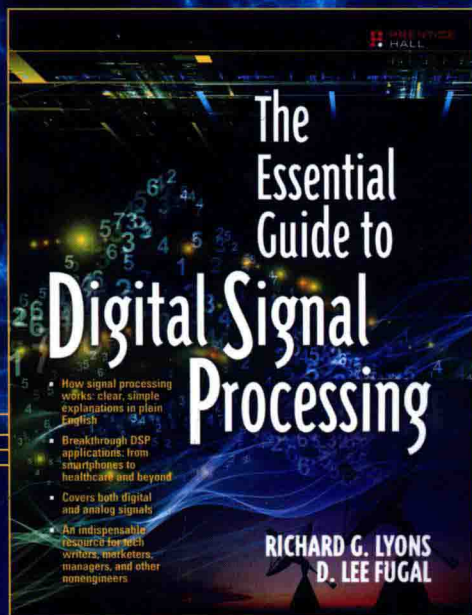
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数字信号处理精要

(英文版)

[美] 理查德 G. 莱昂斯 (Richard G. Lyons) 著
D. 李·富盖尔 (D. Lee Fugal)

*The Essential Guide
to Digital Signal
Processing*



机械工业出版社
China Machine Press

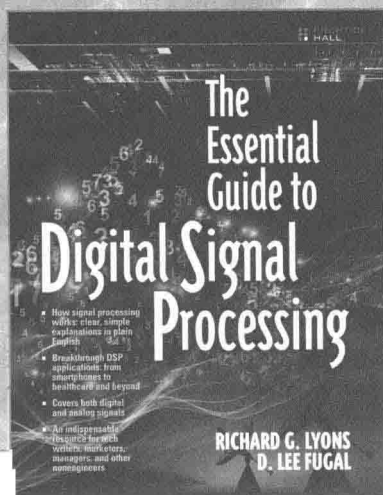
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出版者的话

文艺复兴以来，源远流长的科学精神和逐步形成的学术规范，使西方国家在自然科学的各个领域取得了垄断性的优势；也正是这样的优势，使美国在信息技术发展的六十多年间名家辈出、独领风骚。在商业化的进程中，美国的产业界与教育界越来越紧密地结合，信息学科中的许多泰山北斗同时身处科研和教学的最前线，由此而产生的经典科学著作，不仅擘划了研究的范畴，还揭示了学术的源变，既遵循学术规范，又自有学者个性，其价值并不会因年月的流逝而减退。

近年，在全球信息化大潮的推动下，我国的信息产业发展迅猛，对专业人才的需求日益迫切。这对我国教育界和出版界都既是机遇，也是挑战；而专业教材的建设在教育战略上显得举足轻重。在我国信息技术发展时间较短的现状下，美国等发达国家在其信息科学发展的几十年间积淀和发展的经典教材仍有许多值得借鉴之处。因此，引进一批国外优秀教材将对我国教育事业的发展起到积极的推动作用，也是与世界接轨、建设真正的世界一流大学的必由之路。

机械工业出版社华章公司较早意识到“出版要为教育服务”。自1998年开始，我们就将工作重点放在了遴选、移译国外优秀教材上。经过多年的不懈努力，我们与Pearson、McGraw-Hill、Elsevier、John Wiley & Sons、CRC、Springer等世界著名出版公司建立了良好的合作关系，从他们现有的数百种教材中甄选出Alan V. Oppenheim Thomas L. Floyd、Charles K. Alexander、Behzad Razavi、John G. Proakis、Stephen Brown、Allan R. Hambley、Albert Malvino、Peter Wilson、H. Vincent Poor、Hassan K. Khail、Gene F. Franklin、Rex Miller等大师名家的经典教材，以“国外电子与电气工程技术丛书”和“国外工业控制与智能制造丛书”为系列出版，供读者学习、研究及珍藏。这些书籍在读者中树立了良好的口碑，并被许多高校采用为正式教材和参考书籍。其影印版“经典原版书库”作为姊妹篇也越来越多被实施双语教学的学校所采用。

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前 言

对于“信号”这个词，我们已经很熟悉了。所有承载信息的东西都可以称为信号，例如交通信号、求救信号，甚至还有烟雾信号。在纸牌游戏中，当我们拿到一手好牌的时候，往往尽量不给对方透露任何“信号”。那么，处理信号意味着什么呢？本书将采用现实生活中大家所熟悉的信号和信号处理方法，以最为简洁明了的方式解答这个问题。

大家可能没有意识到，实际上信号和信号处理时时刻刻影响着我们的日常生活。本书不仅展示了为什么信号和信号处理广泛存在于我们的日常生活中，而且更深入地解释了其中的原理。例如，为什么我们从收音机中听到的声音效果要远好于从手机中听到的声音效果？

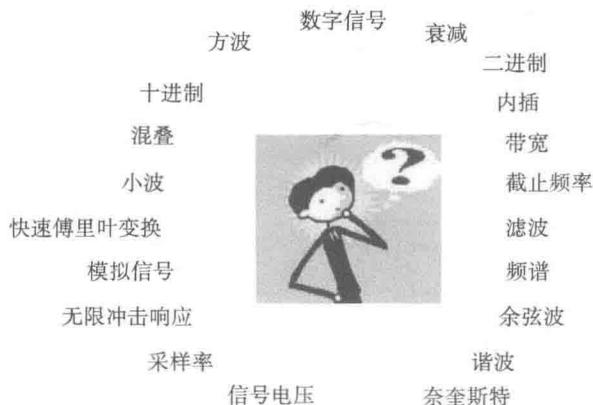
本书面向的读者是非技术类的人群，而不是工程专业的学生。因此，本书的主要目的有两个：首先，采用最少的数学公式，以通俗的方式阐述信号和信号处理的基本概念与原理；其次，介绍信号处理中的“语言”——术语。（为了便于阅读，本书在最后附上了完整的信号处理术语和缩写词。）

对于那些在公司制作或者使用信号处理硬件或软件的非技术类读者，本书将会是你的最佳选择。日常工作中，你可能会碰到许多看似神秘的概念和术语。本书将为你揭开这一层神秘的面纱，让你更深入地理解信号处理，从而更有效地与工程师或者其他技术类人员交流。

通常可以将信号分为两大类：模拟信号和数字信号。本书将逐步解释这两种信号的本质，以及如何在日常生活中使用它们来提高生活品质。

本书的章节是按照作者的理解安排的，你不必按照章节依次阅读，也不见得要阅读整本书。第1章主要介绍信号处理如何在近现代变得如此重要及其原因。第2~5章则阐述模拟信号和数字信号的基本性质。其他章节介绍模拟信号和数字信号的处理方法。

全书的内容大致如此。我们希望你能喜欢这本书，还望它能给你带来帮助。



Contents

1	What Is Digital Signal Processing?	1
	The Phantom Technology	1
	What Is a Signal?	2
	Analog and Digital Signals	3
	Digital Signal Processing	3
	What You Should Remember	5
2	Analog Signals	7
	What Is an Analog Signal?	7
	A Temperature Analog Signal	7
	An Audio Analog Signal	8
	An Electrical Analog Signal	10
	What Is an Electrical Voltage?	10
	Sinusoidal Wave Voltages	13
	Other Useful Periodic Analog Signals	19
	A Human Speech Analog Signal	21
	What You Should Remember	22
3	Frequency and the Spectra of Analog Signals	25
	Frequency	25
	Cycles per Second	26
	Radians per Second	28
	The Concept of Spectrum	29
	Analog Signal Spectra	30
	A Composite-Signal Spectral Example	32
	Harmonics	34
	Harmonic Distortion	37
	Bandwidth	39

The Other Bandwidth 42

What You Should Remember 42

4 Digital Signals and How They Are Generated 43

What Is a Digital Signal? 43

The Notion of Digital 43

Digital Signals: Definition #1 44

Digital Signals: Definition #2 45

How Digital Signals Are Generated 48

Digital Signal Generation by Observation 48

Digital Signal Generation by Software 48

Digital Signal Generation by Sampling an Analog Signal 49

The Sample Rate of a Digital Signal 52

A Speech Digital Signal 53

An Example of Digital Signal Processing 55

Another Example of Digital Signal Processing 57

Two Important Aspects of Sampling Analog Signals 61

Sample Rate Restriction 62

Analog-to-Digital Converter Output Numbers 62

Sample Rate Conversion 63

Decimation 63

Interpolation 63

What You Should Remember 66

5 Sampling and the Spectra of Digital Signals 67

Analog Signal Spectra—A Quick Review 67

How Sampling Affects the Spectra of Digital Signals 71

The Mischief in Sampling Oscillating Quantities 73

Sampling Analog Sine Wave Voltages 76

Why We Care about Aliasing 80

The Spectrum of a Digital Sine Wave Signal 82

The Spectrum of a Digital Voice Signal 85

The Spectrum of a Digital Music Signal 86

Anti-Aliasing Filters 89

Analog-to-Digital Converter Output Numbers 93

What You Should Remember 94

6 How We Compute Digital Signal Spectra 95

Computing Digital Spectra 95

The Discrete Fourier Transform 96

The Fast Fourier Transform 96

A Spectral Computation Example 97

The Computations 97

What the Computations Mean 103

A Spectral Analysis Example 103

What You Should Remember 106

7 Wavelets 107

The Fast Fourier Transform (FFT)—A Quick Review 107

The Continuous Wavelet Transform (CWT) 109

Undecimated or Redundant Discrete Wavelet Transforms (UDWT/RDWT) 114

Conventional (Decimated) Discrete Wavelet Transforms (DWT) 114

What You Should Remember 117

8 Digital Filters 119

Analog Filtering 119

Generic Filter Types 121

Digital Filtering 122

What You Should Remember 126

9 Binary Numbers 127

Number Systems 128

Decimal Numbers, a Base-10 Number System 128

A Base-4 Number System 129

Binary Numbers, a Base-2 Number System 130

Using Binary Numbers at Home 132

Binary Data 133

Why Use Binary Numbers? 134

Digital Hardware Is Easy to Build 134

Binary Data Is Resistant to Degradation 135

Binary Numbers and Analog-to-Digital Converters 136

What You Should Remember 139

A Scientific Notation 141

B Decibels 145

Decibels Used to Describe Sound Power Values 146

Decibels Used to Measure Earthquakes 147

Decibels Used to Describe Signal Amplitudes 149

Decibels Used to Describe Filters 153

C AM and FM Radio Signals 155

AM Radio Signals 155

FM Radio Signals 157

Comparing AM and FM Radio 159

D Binary Number Formats 161

Unsigned Binary Number Format 161

Sign-Magnitude Binary Number Format 162

Two's Complement Binary Number Format 163

Offset Binary Number Format 165

Alternate Binary Number Notation 166

Octal Binary Number Notation 166

Hexadecimal Binary Number Notation 166

Glossary 169

目 录

第 1 章 什么是数字信号处理 1

幻影技术 1

什么是信号 2

模拟信号和数字信号 3

数字信号处理 3

本章要点 5

第 2 章 模拟信号 7

什么是模拟信号 7

温度模拟信号 7

音频模拟信号 8

电子模拟信号 10

什么是电压 10

正弦电压 13

其他有用的周期模拟信号 19

人类语音模拟信号 21

本章要点 22

第 3 章 模拟信号的频率和频谱 25

频率 25

频率的定义 26

频率的表示 28

频谱的概念 29

模拟信号频谱 30

一个复合信号频谱的例子 32

谐波 34

谐波失真 37

带宽 39

带宽的其他定义 42

本章要点 42

第 4 章 数字信号及其产生方式 43

什么是数字信号 43

数字的概念 43

数字信号定义 I 44

数字信号定义 II 45

数字信号的产生方式 48

通过观察产生数字信号 48

通过软件产生数字信号 48

通过采样模拟信号产生数字信号 49

数字信号的采样率 52

语音数字信号 53

数字信号处理例子 1 55

数字信号处理例子 2 57

模拟信号采样的两个重要方面 61

采样率限制 62

模-数转换器输出数字 62

采样率变换 63

抽取 63

内插 63

本章要点 66

第 5 章 数字信号的采样和频谱 67

模拟信号的频谱——快速回顾 67

采样如何影响数字信号的频谱 71

周期振荡信号的采样 73

对模拟正弦电压波的采样 76

我们为什么要关心混叠 80

数字正弦信号的频谱	82	四进制计数系统	129
数字语音信号的频谱	85	二进制计数系统	130
数字音乐信号的频谱	86	二进制数的应用	132
抗混叠滤波器	89	二进制数	133
模-数转换器输出数字	93	为什么使用二进制数	134
本章要点	94	构建数字式硬件比较容易	134
第 6 章 如何计算数字信号的频谱	95	二进制数的可靠性高	135
计算数字频谱	95	二进制数和模-数转换器	136
离散傅里叶变换	96	本章要点	139
快速傅里叶变换	96	附录 A 科学计数法	141
频谱计算实例	97	附录 B 分贝	145
计算实例	97	用分贝来描述声音功率值	146
相关运算的含义	103	分贝在地震测量中的应用	147
频谱分析实例	103	用分贝描述信号的幅值	149
本章要点	106	用分贝描述滤波器	153
第 7 章 小波	107	附录 C 调幅和调频广播信号	155
快速傅里叶变换——快速回顾	107	调幅广播信号	155
连续小波变换	109	频率调制无线电信号	157
非抽取小波变换或冗余离散小波变换	114	比较调幅和调频收音机	159
传统 / 采样离散小波变换	114	附录 D 二进制数格式	161
本章要点	117	无符号二进制数格式	161
第 8 章 数字滤波器	119	原码二进制数格式	162
模拟滤波	119	补码二进制数格式	163
常见滤波器类型	121	移码二进制数格式	165
数字滤波	122	其他二进制数表示法	166
本章要点	126	八进制记数法	166
第 9 章 二进制数	127	十六进制记数法	166
计数系统	128	术语表	169
十进制计数系统	128		

1 What Is Digital Signal Processing?

THE PHANTOM TECHNOLOGY

The technology of digital signal processing (DSP) has affected our modern lives in the most significant ways. If you watch television, connect to the Internet, use a digital camera, make a cell phone call, drive a car, type on the keyboard of a home computer, or use a charge or debit card, you are taking advantage of DSP. In fact, DSP is the technical *brains* in all those devices. Although we take advantage of DSP dozens of times a day, very few people have ever heard of digital signal processing and this strange situation is why DSP has been called a phantom technology. To show how much we depend on this *invisible* DSP technology, Table 1.1 provides a short list of what life would be like without DSP.

Table 1.1 Life without Digital Signal Processing

Missing Technology:	Comments:
No cell or smartphones.	No texting or Web surfing. Anyone remember pay telephones?
No computers.	No Internet, no e-mail, no Facebook, no YouTube, no Skype.
No cable or satellite television.	Viewing restricted to a few local, low-definition TV channels.
No compact discs (CDs).	Go back to audio cassette tapes.
No digital video discs (DVDs).	Who remembers movies on low-definition VHS magnetic tapes?
No charge card purchases	Cash or check only.

(Continues)

Table 1.1 (Continued)

Missing Technology:	Comments:
No digital cameras.	Plan on taking exposed camera film to the drug store.
No ultrasound and no MRI or CAT scans.	Revert to exploratory surgery (opening you up) to investigate internal medical problems.
No Global Positioning System (GPS).	Go back to paper maps.
No Doppler radar.	No long-range weather predictions.
No advanced oil exploration.	Higher gasoline prices. (Yes, even higher.)
No video games.	Kids would have to go outside to play.
No airline flights during bad weather.	Bring your sleeping bag to the airport.
No musical greeting cards.	How boring.

Given that we now realize how important DSP is in our daily lives, it's reasonable to ask just what is this thing called **DSP technology**. To understand the meaning of the phrase *digital signal processing*, we must first explain what we mean by the word *signal*.

WHAT IS A SIGNAL?

Any complete definition of the word *signal* must be, by necessity, somewhat vague. For example, some people define a signal as any representation of information conveyed to a receiver. Rather than discussing the meanings of those defining words, let's clarify what the word *signal* means to us by considering examples of signals that we've experienced in our daily lives. For example, when we listen to music produced by a loudspeaker, we're experiencing a signal in the form of sound waves traveling through the air that stimulates our eardrums. When we drive our cars to a traffic intersection, a light signal radiated by a red or green traffic light tells us whether we should stop or proceed. And if we ignore the red light, we find another red light following us down the road with a siren to *signal* us to pull over!

When you want to make a cell phone call, the symbol on your phone's screen, shown in Figure 1-1, is a visual indicator that your phone is receiving a sufficiently strong radio signal from a local cell phone tower. The height of a thermometer's mercury column is a visual signal indicating temperature. When we receive a kiss on the cheek, that's a tactile signal of affection. All of these examples are instances of receiving a *signal* that conveys information.



Figure 1-1 Cell phone signal-strength indicator.

ANALOG AND DIGITAL SIGNALS.....

As it turns out, all signals fall into one of two major categories, *analog signals* and *digital signals*. The signals that we experience in our daily lives, the examples of sound and light signals mentioned in the previous section, are **analog signals**. Chapters 2 and 3 discuss analog signals in more detail.

Strangely enough, **digital signals** are nothing more than sequences of numbers. It's true—sequences of numbers that can be stored in the electronic memories of computers, digital cameras, and video game machines, or recorded on CDs and DVDs. Signal processing engineers have developed a way to convert analog signals, such as a sound or light signal, into digital signals (sequences of numbers). The digital signals contain *all* the information of the original analog signals. In addition, signal processing engineers have also developed the means to convert a digital signal back into an analog signal (sound or light). Converting an analog signal to a digital signal and then converting the digital signal back into an analog signal doesn't seem too useful, but that's where digital signal processing comes in.

DIGITAL SIGNAL PROCESSING

Digital signal processing is the mathematical manipulation of the numerical values of a digital signal that changes the digital signal in some advantageous way. For example, let's say a vocalist is singing into a microphone and we convert that analog voice signal to a digital signal. Next, the values of the numbers in the digital signal can be modified such that when the modified digital signal is converted back to an analog signal and played through a loudspeaker, we hear a slight echo in the singing that gives us a more pleasant sound. Manipulating pop singers' voices is standard operating procedure in today's music business. We discuss that topic in more detail in Chapter 4.

For a more serious example of digital signal processing, consider undergoing an electrocardiogram (EKG or ECG) test to check for problems with the electrical activity of your heart. Small electrodes, taped to your chest, detect an analog electrical signal produced by your heart that often looks like that shown in Figure 1-2(a). For various practical reasons, the analog electrode signal is contaminated with abrupt,

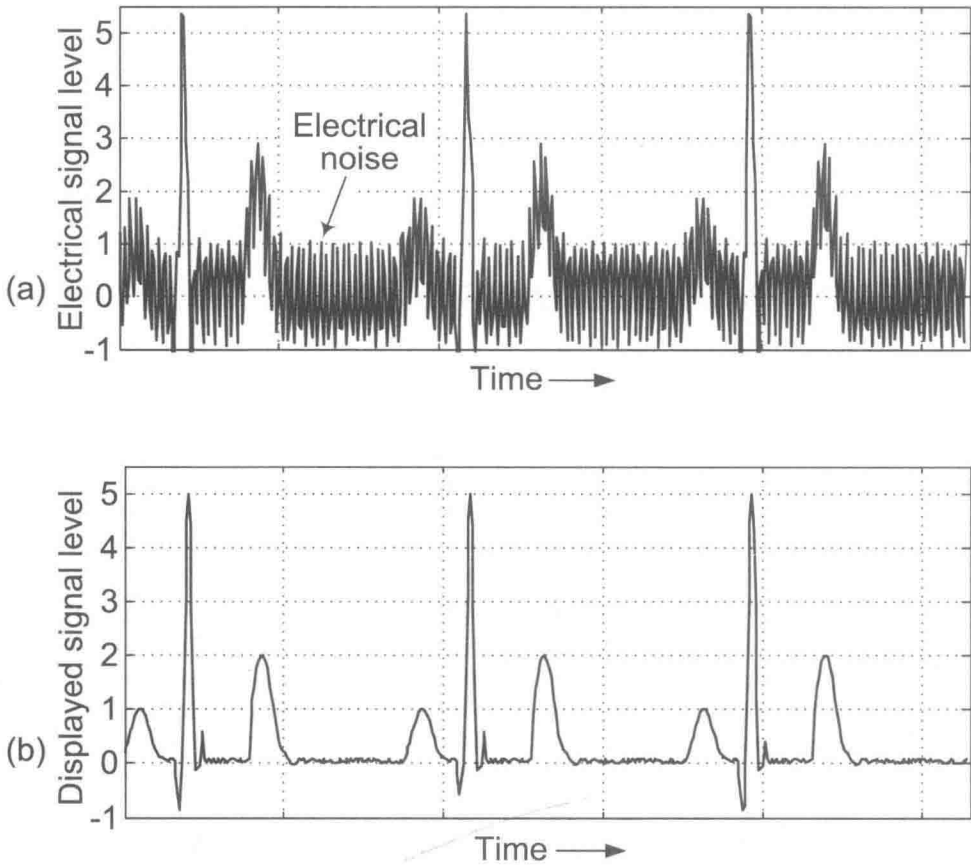


Figure 1-2 Electrocardiogram signals: (a) original measured noisy signal; (b) improved signal display after digital signal processing.

unwanted signal-level fluctuations, called **noise**, making it impossible for a doctor to evaluate your heart's electrical activity.

Today, digital signal processing comes to the rescue. As shown in Figure 1-3, the analog electrical sensor signal is converted to a digital signal. Next, the numerical values in the digital signal are modified in a way that eliminates the unwanted noise portion of the signal. The result is a clean EKG display, as shown in Figure 1-2(b), enabling a doctor to quickly evaluate the health of your heart.

Other applications for DSP include military, industrial, space exploration, photography, communications, scientific, seismic, weather and many more. As we showed earlier in Table 1.1, life would go on without the benefits of DSP. However, we would have to do without so very many conveniences that we currently enjoy.

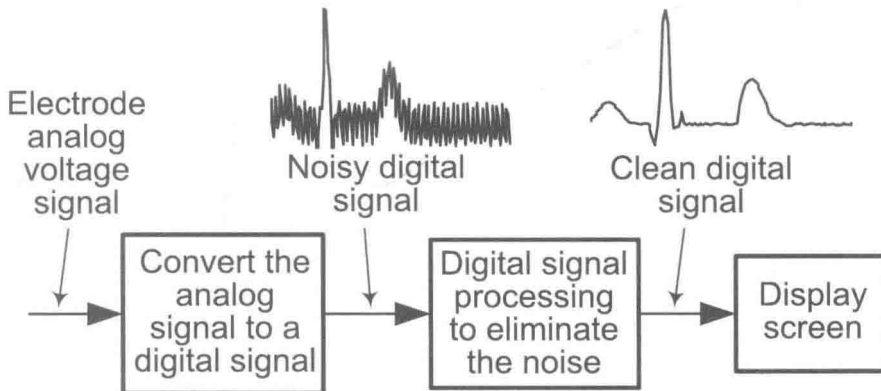


Figure 1-3 Using digital signal processing to improve an electrocardiogram signal display.

OK, this concludes our super-brief introduction to analog and digital signals, and digital signal processing. In later chapters, we'll learn more details about signals and signal processing.

WHAT YOU SHOULD REMEMBER

The concepts you should remember from this chapter are:

- We experience signals throughout our daily lives, usually in the form of analog sound and light signals.
- There is a way to convert analog signals, such as sound or light signals, into digital signals (sequences of numbers) that are stored in an electronic device. The digital signals contain *all* the information of the original analog signals.
- The numbers in a digital signal can be mathematically modified to improve some important characteristic of the signal, or reduce unwanted noise that contaminates it.
- The processed (modified and improved) digital signal can be converted back into an analog signal if necessary.
- The applications of DSP are many and varied. We may not always see where this phantom technology of DSP is used, but our lives would be very different without it.

