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内 容 简 介

本书介绍了ΔΣ模数及数模转换器的原理，引入了计算机辅助分析和设计技术。由于Delta-Sigma数据转换的原理有着广泛的应用范围，不仅限于数据转换器，所以本书涉及面广，包括数字电话、数字音频、无线及有线通信、医疗电子等中的ΔΣ转换器。作者强调实际操作而不是复杂的数学推导，通过一阶ΔΣ调节器引出二阶及高阶调节器，同时讨论了实现方法，给出了设计实例。本书从基本概念开始，由浅入深地介绍了Delta-Sigma转换器，并结合实例帮助读者理解，因此适应各个层次的研究者，既适合于Delta-Sigma数据转换的初学者，同时适合高年级本科生和研究生。

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《国外电子信息精品著作》序

20世纪90年代以来，信息科学技术成为世界经济的中坚力量。随着经济全球化的进一步发展，以微电子、计算机、通信和网络技术为代表的信息技术，成为人类社会进步过程中发展最快、渗透性最强、应用面最广的关键技术。信息技术的发展带动了微电子、计算机、通信、网络、超导等产业的发展，促进了生命科学、新材料、能源、航空航天等高新技术产业的成长。信息产业的发展水平不仅是社会物质生产、文化进步的基本要素和必备条件，也是衡量一个国家的综合国力、国际竞争力和发展水平的重要标志。在中国，信息产业在国民经济发展中占有举足轻重的地位，成为国民经济重要支柱产业。然而，中国的信息科学支持技术发展的力度不够，信息技术还处于比较落后的水平，因此，快速发展信息科学技术成为我国迫在眉睫的大事。

要使我国的信息技术更好地发展起来，需要科学工作者和工程技术人员付出艰辛的努力。此外，我们要从客观上为科学工作者和工程技术人员创造更有利于发展的环境，加强对信息技术的支持与投资力度，其中也包括与信息技术相关的图书出版工作。

从出版的角度考虑，除了较好较快地出版具有自主知识产权的成果外，引进国外的优秀出版物是大有裨益的。洋为中用，将国外的优秀著作引进到国内，促进最新的科技成就迅速转化为我们自己的智力成果，无疑是值得高度重视的。科学出版社引进一批国外知名出版社的优秀著作，使我国从事信息技术的广大科学工作者和工程技术人员能以较低的价格购买，对于推动我国信息技术领域的科研与教学是十分有益的事。

此次科学出版社在广泛征求专家意见的基础上，经过反复论证、仔细遴选，共引进了接近30本外版书，大体上可以分为两类，第一类是基础理论著作，第二类是工程应用方面的著作。所有的著作都涉及信息领域的最新成果，大多数是2005年后出版的，力求“层次高、内

容新、参考性强”。在内容和形式上都体现了科学出版社一贯奉行的严谨作风。

当然，这批书只能涵盖信息科学技术的一部分，所以这项工作还应该继续下去。对于一些读者面较广、观点新颖、国内缺乏的好书还应该翻译成中文出版，这有利于知识更好更快地传播。同时，我也希望广大读者提出好的建议，以改进和完善丛书的出版工作。

总之，我对科学出版社引进外版书这一举措表示热烈的支持，并盼望这一工作取得更大的成绩。



中国科学院院士
中国工程院院士
2006 年 12 月

Foreword

In the next few remarks, we shall explain our reasons for writing this book. Since its inception in the early 1960s, delta-sigma modulation has evolved through a number of generations and now stands as one of the more popular methods for constructing high-performance analog-to-digital and digital-to-analog converters. The concept of noise-shaping, which is central to delta-sigma modulation, continues to be refined and to be applied to new areas. The technical literature contains a wealth of information regarding various aspects of delta-sigma modulation, but the sheer volume of this material acts as a barrier to the designer who is embarking on his first trip into the land of delta-sigma.

Earlier works to which we contributed served the need for a guide by cataloging publications and republishing a subset of them [1], or by enlisting the help of a collection of authors [2]. This book, in contrast, provides a coherent and consistent entry-level reference into the world of delta-sigma. The introductory chapter is, in essence, a generalist's guide. That chapter is devoted to introducing main roads and to identifying major landmarks, and so should chart some territory which is unfamiliar to the reader. Do not despair if you feel a little lost, since if you understand that chapter completely you do not deserve to be called a beginner! The remainder of the text plots a more deliberate course through the countryside, one

which allows time for exploring some of the side roads and for pondering a number of the more remarkable edifices which dot the landscape.

Unfortunately, the text is by no means all-inclusive. In order to have a non-zero probability of completing this work in a reasonable amount of time, we have had to make difficult decisions regarding what material would be appropriate for an introductory text and what material could be omitted. We hope that the reader will find the route we have chosen makes a pleasant and satisfying journey, and we trust that the many researchers and designers who cut roads through the wilderness will find their hard work adequately acknowledged. As always, the blame for any omissions or misdirections lies with us. Let us know if you encounter any.

Bon voyage!

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[1] *Oversampling Delta-Sigma Data Converters*, J. C. Candy and G. C. Temes, Eds. New York: *IEEE Press*, 1991.

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CHAPTER 1 *Introduction*

In this introductory chapter, the need for oversampling data converters will be discussed, and their performance contrasted with that of Nyquist-rate converters. Delta modulation and delta-sigma modulation will be described and compared. The basic architectures for delta-sigma ($\Delta\Sigma$) modulators will be presented, and newer trends identified.

1.1 The Need for Oversampling Converters

Computational and signal processing tasks are now performed predominantly by digital means, since digital circuits are robust and can be realized by extremely small and simple structures which can in turn be combined to obtain very complex, accurate and fast systems. Every year, the speed and density of digital integrated circuits (ICs) is increased, enhancing the dominance of digital methods in almost all areas of communications and consumer products. Since the physical world nevertheless remains stubbornly analog, data converters are needed to interface with the digital signal processing (DSP) core. As the speed and capability of DSP cores increases, so too must the speed and accuracy of the converters associated with them.

Fig. 1.1 illustrates the block diagram of a signal processing system with analog input and output signals, plus a central digital engine. As shown, the analog input signal (usually after some amplification and filtering) enters an analog-to-digital converter (ADC) which transforms it into a digital data stream. This stream is processed by the DSP core, and the resulting digital output signal is reconverted into analog form by a digital-to-analog converter (DAC). The DAC output is usually also filtered and amplified to obtain the final analog output signal.

Data converters (both ADCs and DACs) can be classified into two main categories: *Nyquist-rate* and *oversampled* converters. In the former category, there exists a one-to-one correspondence between the input and output samples. Each input sample is separately processed, regardless of the earlier input samples; the converter has no memory. Thus, applying a digital input word containing bits $b_1, b_2, \ldots b_N$ to a Nyquist-rate DAC ideally results in an analog output

$$V_{out} = V_{ref}(b_1 2^{-1} + b_2 2^{-2} + \ldots + b_N 2^{-N}), \tag{1.1}$$

(where V_{ref} is the reference voltage) regardless of any previous input word. The accuracy of conversion can be evaluated by comparing the actual value of V_{out} with the ideal value given by (1.1).

As the name implies, the sampling rate f_s of Nyquist-rate converters can be as low as Nyquist's criterion requires, i.e., twice the bandwidth f_B of the input signal. (For practical reasons, the actual rate is usually somewhat higher than this minimum value.)

In most cases, the linearity and accuracy of Nyquist-rate converters is determined by the matching accuracy of the analog components (resistors, current sources or

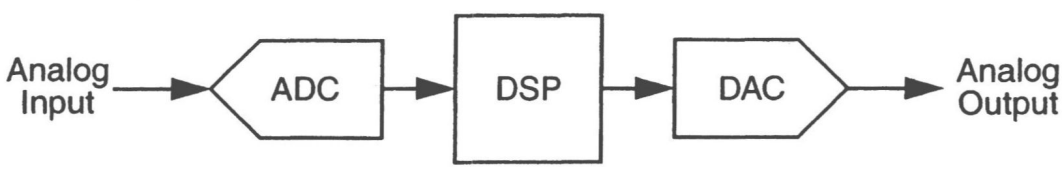


Figure 1.1: A modern signal processing system contains a DSP core bracketed by data converters.

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