ANALOG DEVICES TECHNICAL HANDBOOKS

Published by Prentice-Hall
  Analog-Digital Conversion Handbook

Published by Analog Devices
  Nonlinear Circuits Handbook
  Transducer Interfacing Handbook
  Synchro & Resolver Conversion
ANALOG-DIGITAL CONVERSION HANDBOOK

by
The Engineering Staff of
Analog Devices, Inc.

Edited by Daniel H. Sheingold

PRENTICE-HALL, Englewood Cliffs, NJ 07632
Library of Congress Cataloging in Publication Data: 85-62726

ISBN: 0-13-032848-0

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Printed in the United States of America
10 9 8 7 6 5 4 3 2 1

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ISBN 0-13-032848-0  025

Prentice-Hall of Australia Pty. Limited, Sydney
Prentice-Hall Canada Inc., Toronto
Prentice-Hall Hispanoamericana, S.A., Mexico
Prentice-Hall of India Private Limited, New Delhi
Prentice-Hall of Japan Inc., Tokyo
Prentice-Hall of Southeast Asia Pte. Ltd., Singapore
Whitehall Books Limited, Wellington, New Zealand
Contents in Brief

Contents in Brief – v  Contents – vii  Preface – xvii

Part I: Converters at Work (With and Without Microprocessors)

1 Introduction: Data Systems and Components – 3
2 Data Acquisition – 17
3 Data Distribution – 49
4 System Integration and Remote Data Acquisition – 67
5 Analog Functions with Digital Components – 107
6 Applications of Converters in Instruments and Systems – 133

Part II: A/D and D/A Converters

7 Understanding Converters – 169
8 Converter Microcircuits – 221
9 Converter Design Insights – 277
10 Testing Converters – 297
11 Specifying Converters – 343
12 Applying Converters Successfully – 371

Part III: Analog-Digital Converters for Special Applications

13 Video Converters – 403
14 Converters for Resolvers and Related Devices – 441
15 V/F and F/V Converters – 473
16 Intentionally Nonlinear Converters – 513
17 High-Resolution Converters – 531

Part IV: Related Circuits and Devices (Data-Acquisition-Peripherals)

18 Sample-Hold Circuits – 559
19 Analog Switching and Multiplexing – 573
20 Reference Circuits – 599
21 Digital Signal-Processing ICs – 621

Part V: Guide for the Troubled – 659

Bibliography – xxiii  Index – xxxiii
Table of Contents

Contents in Brief .................................................. v
Contents ............................................................... vii
Preface ............................................................... xvii

Part I: CONVERTERS AT WORK (WITH AND WITHOUT MICROPROCESSORS)

1. Introduction: Data Systems and Components ............... 3
   Analog vs. Digital; The Most Important Element; Sensors; Operational Amplifiers; Instrumentation Amplifiers; Isolators; Analog Function Circuits; Analog Multiplexers; Digital Multiplexing; Sample/Track-Hold Circuits; A/D Converters; D/A Converters; Registers; Digital Data Processors; Up-Down Counters; Filters; Comparators; Power Supplies; Digital Panel Instruments; Dedication

2. Data Acquisition ................................................. 17
   2.1 Then and Now ................................................. 18
   2.2 Environment and Complexity ............................... 19
   2.3 Key Factors .................................................. 20
   2.4 Single-Channel Conversion Subsystems. Sample-Hold and Conversion; Sample, Signal, Noise, and Aliasing; Preamplification; Signal Conditioning .......................... 22
   2.5 Multi-Channel Conversion. Multiplexing the Outputs of Single-Channel Converters; Examples of Multiplexed Con-
3. **Data Distribution** .................................................. 49
   3.1 Factors Affecting Distribution-System Design ........... 50
   3.2 Digital Signal Source ........................................... 51
   3.3 Registers ......................................................... 51
   3.4 Multiple Ranks .................................................... 53
   3.5 More Than One Channel. Comparing Sample-Holds and DACs; Analog Data Distribution ......................... 54
   3.6 Acquisition and Distribution ................................... 59
   3.7 Filtering and Deglitching ....................................... 60
   3.8 Minimizing Calibration Errors by Servoing ............... 62
   3.9 Isolation ............................................................ 64

4. **System Integration and Remote Data Acquisition** ................. 67
   4.1 Subsystems for Interfacing Converters to the Analog and Digital Worlds. Integrated-Circuit A/D Converter; Data-Acquisition System; 8-Bit, 8-Channel Memory DAS; uP-Based Thermocouple Meter; Microcomputer Bus-Compatible Analog Input and Output Subsystems; Programmable Single-Board Measurement-and-Control System; Computer-Based Measurement-and-Control System . 68
   4.2 Interfacing Converters with Microprocessors, Using Parallel Connections. Microprocessor Interfacing, I/O vs. Memory; Interfacing an IC 12-Bit A/D Converter with Microprocessors; Interfacing a Data-Acquisition Module to the 8080; Interfacing an IC DAS to the Bus; Interfacing Analog I/O Boards to Microcomputer Buses ......................... 83
   4.3 Serial Interfacing. ASCII; RS232C and Other Standards; Communications Protocols ............................. 96

5. **Analog Functions with Digital Components** .......................... 107
   5.1 Sources. Digitally Controlled Voltage Source; Manual Digital Inputs: Thumbwheel Switch Encoder, Toggle-Switch Register; Digitally Controlled Current Sources: “Current-Output” DAC, Current Gain – Floating Load, Current Gain – Buffered Load, Current to Grounded Load, 4-to-20-mA Current Generators ......................... 109
5.2 Scale Factors. Digitally Controlled Scale Factors: Direct Scale Factor, Inverse Scale Factor, Logarithmic Scale Factors, High-Precision Multiplication ... or Division ... 117
5.3 Functional Relationships: Arbitrarily Programmable Functional Relationships, Sinusoidal Input-Output Relationships .......................... 121
5.4 Trigonometric Applications: Digital Phase Shifter, Digital/ Resolver Converter (Resolver Simulator), Coordinate Conversion .......................... 122
5.5 Waveform Generation: Sawtooth Generator, Triangular-Wave Generator, Sine-Wave Generator, Digital-to-Frequency Conversion ...................... 124
5.6 Time Responses: Precision Analog Delay Line, Tapped Delay Line, Serial Delay Line .......................... 127
5.7 Digital Servo Circuits: Tracking Sample-Hold (A/D Con- verter, Digital Pulse Stretcher, Digital Peak-Follower (with Hysteresis), Automatic Set-Point Circuit .......................... 129
5.8 A Final Note: Software vs. Hardware .......................... 132

6. Applications of Converters in Instruments and Systems ... 133
6.2 Digital Signal Processing. Shift-Register Delay Line: Readout into Memory, Readout as an Analog Signal, Recirculate, Perform Waveform Averaging by Addition, Time Compression by Sampling, Real-Time Correlation, Incremental Delay Line as a Filter, Recursive Filtering; Conclusion .......................... 140
6.4 Commerce, Industry, and Elsewhere: Electronic Instru- ments, Medical Imaging, Industrial Automation, Oil-Well Monitoring .......................... 159

Part II: A/D AND D/A CONVERTERS
7. Understanding Converters .......................... 169
7.1 Binary Codes and Conversion Relationships. Analog Quantities; Digital Quantities; Binary Code—Integers and Fractions; Basic Conversion Relationships .......................... 169
7.2 Other Codes. Binary-Coded Decimal (BCD): Overtanding; Gray Code; Complementary Codes .......................... 177
7.3 Analog Polarity and Scaling. Bipolar Codes: Sign-Magnitude, Offset Binary, Twos Complement, Ones Complement; Code Conversion; Other Bipolar Codes; Arbitrary Biasing and Scaling; DACs as Multipliers and ADCs as Dividers ................................................................. 183
7.4 Electrical Interfaces with Converters. Ground Rule; Power Supplies; Digital Logic Levels; Control Logic: The Status Output, The Strobe; Analog Signals ................................. 191
7.5 D/A Converter Circuits. Switch Decoding; Resistance Ladders; Switching; References; Bipolar Conversion; Registers on DACs .................................................. 199
7.6 A/D Converter Circuits. Successive Approximations; Integration (Ramp and V/F Types); Counter and Servo Types; Parallel Types; A Note on Shared Logic .......... 211

8. Converter Microcircuits .............................................. 221
8.1 Integrated-Circuit Converters. Processes: Bipolar/IIL, CMOS, BiMOS, Hybrid ........................................... 221
8.2 Bipolar (Process) D/A Converters: 12-Bit DAC, Adding a Reference, Increasing the Speed, Adding Latches, Output Amplifier, Putting it All Together; Complete 8-Bit DACs: Keys to the Complete 8-Bit DAC, Easy to Interface ........................................ 224
8.3 CMOS D/A Converters. CMOS D/A Conversion; Equivalent Circuit; Digital Buffering; Analog Considerations; Multiple Converters: Filter Application, DACs as Parameter-Control Elements, Programming the Parameters, Quad Voltage-Output DAC; Partially Decoded DACs for Higher Resolutions ......................................................... 235
8.4 BiMOS DAC Technology ................................................ 255
8.5 Hybrid DACs ............................................................... 258
8.6 Integrated-Circuit A/D Converters; Bipolar Processing with IIL: 8- and 10-Bit ADCs, 12-Bit ADCs, 8-Bit ADC with Simplified Logic and Instrumentation-Amplifier Input; CMOS A/D Converters: 8-Bit A/D Converters (Timing and control, Synchronous conversion mode, Slow memory interface, ROM interface, Asynchronous conversion mode), 12-Bit CMOS A/D Converters ........................................ 260

9. I.C. Converter Design Insights ........................................ 277
9.1 Review of D/A Converter Techniques: R-2R Ladder Networks, Getting the Currents Out, Switching, Output Current Scaling, Correcting \( V_{BE} \) Differences, Offsetting the Base Voltages .................. 277
9.2 Applying the Techniques to the Final Product ............................................ 293
9.3 Laser-Wafer-Trimming ..................................................................................... 295

10. Testing Converters ......................................................................................... 297
10.1 D/A Converter Transfer Function ................................................................. 298
10.2 D/A Converter Specifications. End-Point Errors; Linearity; Superposition .......... 300
10.3 D/A Converter Testing. Static Errors: Major-Carry Technique, Bit-Scan Testing; DAC Settling-Time Measurement ....................................................... 307
10.5 Practical Considerations. Transition Uncertainty; Hardware Constraints: Grounding, Input Buffer; Testing Under Dynamic Conditions: Analog Waveform Reconstruction, Digital Waveform Analysis .......................................................... 335

11. Specifying Converters ..................................................................................... 343
11.1 Two Basic Factors ......................................................................................... 344
11.2 Defining the Objectives—Application Checklists: General Considerations, Considerations for D/A Converters, Considerations for A/D Converters, Considerations for Analog Multiplexers and Sample-Holds .................................................. 344
Uncertainty, Ratiometric, Resolution, Sample-to-Hold Offset, Settling Time, Single-Slope Conversion, Slewing Rate, Stability, Staircase, Subranging A/D Converter, Successive Approximations, Switching Time, Temperature Coefficient (Gain, Linearity, Zero TC, Offset), Thermal Tail, Total Unadjusted Error, Zero- and Gain-Adjustment 348

11.4 System-Component Selection Process 366
11.5 An Example of a Selection and Verification Process. First Approximation, Error Analysis: Multiplexer, Sample-Hold, Converter 367

12. Applying Converters Successfully 371
12.1 Making the Proper System Choices. Data-Acquisition Systems; Three Classes of Converter Specifications; Approaches to Relaxing the Specifications; Logarithmic Compression; Filtering; Sample-Hold; Driving the A/D Converter; Contributions to Error 372
12.2 Installation and Grounding. Grounding; Reducing Common-Mode Errors 380
12.3 How to Adjust Zero and Gain of Converters. Adjustment Process; Adjustment for DACs; Adjustment for ADCs 385
12.4 Other Ways to Improve Performance. Preserving DAC Analog Output Accuracy: Dynamic Problems, Offset Problems in CMOS DACs; More on Bypassing and Grounding: Substitutes for Ground 387

Part III: ANALOG-DIGITAL CONVERTERS FOR SPECIAL APPLICATIONS

13. Video Converters 403
13.1 Applications Overview. Display Systems; Digital Signal Processing: Digital Fluorography, Phased-Array Ultrasound; Radar; Transient Detection; Communications: Fibre Optics and Satellite Communication, FDM/TDM Transmultiplexers 403
13.3 Practical Design Insights. Board-Level Grounds; Layout;
<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>14.</td>
<td>Converters for Resolvers and Related Devices</td>
<td>441</td>
</tr>
<tr>
<td>14.1</td>
<td>Position Measurement in Perspective. Optical Encoders; Potentiometers, Contact Encoders, RVDTs, LVDTs, and Glass Scales; Resolvers and Synchros; Inductosyns; Comparing Alternatives</td>
<td>442</td>
</tr>
<tr>
<td>14.2</td>
<td>Resolver-to-Digital Converters. Tracking Converters; Phase-Analog Approach; Successive-Approximation Approach; Tachometer Outputs</td>
<td>451</td>
</tr>
<tr>
<td>14.3</td>
<td>Digital-to-Resolver Converters</td>
<td>458</td>
</tr>
<tr>
<td>14.4</td>
<td>Designing with Resolvers, Synchros, Inductosyns, and Converters. Designing with Resolvers and Synchros: Transducer Accuracy and Size, Converter Accuracy, System Accuracy, Worst-Case Accuracy, Tracking Rate, Multiple-Speed Resolvers, Frequency; Designing with Rotary Inductosyns: Converter Accuracy, System Accuracy, Tracking Rate; Designing with Linear Inductosyns: Resolution, Converter Accuracy, System Accuracy, Worst-Case Accuracy, Velocity; Designing with Digital-to-Resolver/Syncher Converters</td>
<td>461</td>
</tr>
<tr>
<td>14.5</td>
<td>Applications of Resolvers, Synchros, Inductosyns, and Converters. Machine-Tool Applications; Gun Control; Plan-Position Indicator</td>
<td>467</td>
</tr>
<tr>
<td>15.</td>
<td>Voltage-to-Frequency Converters</td>
<td>473</td>
</tr>
<tr>
<td>15.1</td>
<td>Introduction</td>
<td>473</td>
</tr>
<tr>
<td>15.2</td>
<td>Definitions and Specifications: Offset, Dynamic Range, Linearity, Gain, Gain Tempco, Power-Supply Rejection Ratio</td>
<td>475</td>
</tr>
<tr>
<td>15.3</td>
<td>Survey of VFC Devices. Multivibrator Types; Charge-Balance Types, Synchronous VFCs; Assembled Modular Devices</td>
<td>479</td>
</tr>
<tr>
<td>15.4</td>
<td>Applications. VFC Voltmeter; Signal Isolation: Signal Reconstruction; Phase-Locked-Loop F/V Conversion: PLL Performance; Synchronous VFC Applications</td>
<td>490</td>
</tr>
<tr>
<td>15.5</td>
<td>Practical Matters. Decoupling and Grounding; Component Selection</td>
<td>509</td>
</tr>
</tbody>
</table>
16. Intentionally Nonlinear Converters ........................................ 513
   16.1 Why Intentionally Nonlinear Converters? .......................... 514
   16.2 Understanding the LOGDAC. What the Specifications Mean .......... 514
   16.3 Applications of LOGDACs. Basic Attenuator or Digital Potentiometer; Exponential Amplifier or Pot with Feedback; Logarithmic A/D Converter; Range Extension ........ 524

17. High-Resolution Data Conversion ......................................... 531
   17.1 Applications ................................................................. 532
   17.2 High-Resolution D/A Converters. Testing DAC Integral and Differential Nonlinearity; Maintaining High Resolution and Accuracy; Dynamic Applications of DACs: Important Specifications; Testing Harmonic Distortion of DACs; Improving Dynamic Performance of High-Resolution DACs; Bipolar-Output DAC Performance; Extended Resolution ........ 533
   17.3 High-Resolution A/D Converters. Floating-Point Converters; Extended-Resolution ADCs; Challenges in Designing a High-Resolution A/D Converter; A Little Noise Theory; Board Layout Considerations for High-Res ADCs ........ 546
   17.4 High-Resolution Sample-Holds ........................................... 555

Part IV: RELATED CIRCUITS AND DEVICES (DATA-ACQUISITION-PERIPHERAL COMPONENTS)

18. Sample-Hold Circuits ...................................................... 559
   18.1 Sample-Hold Operation .................................................. 560
   18.2 Specifications. Track Mode: Offset, Nonlinearity, Gain, Settling Time, Bandwidth; Track-to-Hold Transition: Aperture Time, Sample-to-Hold Offset (Pedestal), Aperture Delay, Aperture Uncertainty (Jitter), Switching Transient, Switch Delay Time; Hold Mode: Droop, Feedthrough, Dielectric Absorption; Hold-to-Sample Transition: Acquisition Time ................................................................. 560
   18.3 Sample-Hold Circuits. Open-Loop Circuits; Closed-Loop Circuits ................................................................. 565
   18.4 Applications ................................................................. 568
   18.5 Selecting and Using SHAs ................................................. 571

19. Analog Switching and Multiplexing ..................................... 573
   19.1 Popular Switch Processes. Junction FET Types; PMOS
Types; CMOS Types: Junction-Isolated CMOS, Dielectrically Isolated CMOS; Switch Forms ............... 573
19.2 Switch Characteristics and Specifications. $R_{ON}$ Variation with Signal Voltage; Switch Leakage; Charge Injection; Pumpback; Switching Speed; Settling Time; OFF Isolation; Insertion Loss; Crosstalk ................. 578
19.3 Multiplexing and Multiple Switches. Low-Level-Signal Multiplexing; Multi-Rank Multiplexing; Multiple-Switch Configurations .............................................. 588
19.4 Applications. Sample-and-Hold; DAC Deglitching; DAC Output Demultiplexing; Other Significant Applications: Programmable-Gain Amplifier; A/D Converter Input Auto-ranging ............................................. 593

20. Voltage References ........................................ 599
20.1 Where References are Used .............................. 599
20.2 Types of References. Zener-Diode References: How the Zener Diode Works, Zener Diode Performance; Temperature Compensation, IC Zeners, Reference Circuitry Using Zener Diodes, Buried-Zener References; Temperature-Stabilized References; Bandgap References: Circuit Operation, Using Bandgap References .................. 600
20.3 What the Specifications Mean. Initial Accuracy; Output Voltage Change with Temperature; Line Regulation; Load Regulation; Long-Term Stability .................. 614

21. Digital Signal Processing ICs .............................. 621
21.1 Signal-Processing Basics. Spectral Analysis; Digital Filtering: Finite-Impulse-Response (FIR), Infinite Impulse Response (IIR); Other DSP Algorithms ............... 622
21.2 DSP Hardware. Single-Chip Processors; Microcoded Systems; Fixed-Point Options; Floating-Point Options; Representative Systems .............................................. 635
21.3 DSP Applications. Modems; Studio Recording; Ultrasound Imaging; Vibration Analyzers .................. 646
21.4 Glossary of DSP Terms: Accumulator, Algorithm, ALU, Attenuation, Barrel Shifter, Biquad, Block Floating Point, Convolution, Correlation, Digital Signal Processing, Discrete Fourier Transform (DFT), Fast Fourier Transform (FFT), FIR Filter, Fixed-Point Arithmetic, IIR Filter, MAC, Microcode, Passband, Pipeline, Rolloff, Stopband . 654
Part V: SOURCES OF HELP

22. Guide for the Troubled ........................................... 659
    22.1 Frequently Asked Questions ................................. 660
    22.2 Frequently Encountered Problems. Gross Malfunctions;
        Poor Functioning ........................................... 662
    22.3 Frequently Given Advice. Preventive; Measuring Devices;
        Measuring and Trouble-Shooting ............................ 666
    22.4 If All Else Fails ...! ........................................ 668

Bibliography ........................................................... xxiii
Index ................................................................. xxxiii
Preface

This book is about circuits and systems that interface between the analog variables of the real world and the digital world of processing, storage, communication, and display; almost invariably, such systems employ some form of analog-to-digital and digital-to-analog conversion.

Our principal objective is to provide engineers and scientists on both sides of the interface with the basic information they need to use conversion in a wide variety of settings. The range is from simple converters as circuit elements to converters with displays (digital panel instruments) to fully integrated intelligent data-acquisition systems employing converters "somewhere inside."

Since our readers will come from widely differing backgrounds, in terms of both the range of disciplines normal to the interface—from pure software to purely analog hardware—and, in the real world, from the gamut of disciplines in engineering, science, and physics, a key first step is to provide the common ground of understanding of the role of conversion in typical settings. This is accomplished in Part I, "Converters at Work (With and Without Microprocessors)."

In Part II, "A/D and D/A Converters," you can find basic information for an understanding of converter circuits, and how they communicate at both ends, inspect a sampling of the many available "mainline" converter products, and learn how they are designed, tested, specified, and applied for best results.

Part III treats of some converter forms designed for special areas of application. These include video converters, converters for synchros and resolvers,
voltage-to-frequency converters, and intentionally nonlinear converters.

Part IV discusses some related circuits: analog references, sample-holds, switches and multiplexers, and a review of digital signal processing.

Depending on when it is consulted, Part V, a “Guide for the Troubled,” will be an aid to either avoidance or cure (preferably the former) of problems often encountered by unsuspecting circuit and systems designers in the neighborhood of the interface.

For those desiring greater depth, we have provided a multidimensional bibliography, which is capable of fanning out to the many good in-depth sources of material on conversion. For those desiring to consult specific topics within this book after (or instead of) reading, we have provided a conscientiously detailed Index.

This book, a milestone rather than a culmination, is the third-generation outgrowth of a series of conversations with Ray Stata and Jim Pastoriza in the late 1960s and early 1970s. At that time (and increasingly since then), it was felt that the growing availability of data-processing facilities at low cost—especially minicomputers—would bring the analog-digital interface, in the form of modular a/d and d/a converters and accessories, out of the specialty houses and into the realm of the working design engineer.

Although there are books in print on digital, analog, and hybrid computing, on circuit design, and on digital communication theory and sampled-data systems, there were—and still are—few if any books that could serve as a guide to the engineer on the practical aspects of understanding, specifying, and applying the commercially available elements of conversion systems in these pursuits.

Lest any reader either expect or question our altruism in publishing this book, let us say that our viewpoint and credentials are those of a major producer of precision integrated circuits, modules, subsystems, and computer-based data-acquisition systems, for whatever level of system integration the user is comfortable with. Since we strive neither to hide nor to unduly emphasize our commercial motives, the reader may find that the resulting honesty will impart a down-to-earth sense of practicality and realism.

We have, however, attempted to restrain our temptations to crass commercialism to the extent of using model numbers and product specifications in the text for their flesh-and-blood illustrative effect only. Our catalogs, data sheets, hardware and software manuals, and other propaganda (and those of our competitors) are separately available in sufficient panoply, partisan quality, and timeliness—as well as depth of detail—to make any effort to outshine them in the present volume less than desirable, even if possible.
PREFACE TO THE 1986 EDITION

This volume is a successor to the Analog-Digital Conversion Handbook, first published in 1972, and its interim revision, the Analog-Digital Conversion Notes, published in 1977, which contained Parts I and II of the earlier book, updated to reflect the revolution in cost, size, and performance brought about by IC and hybrid technology—and incorporated two entirely new chapters to further reflect the changes in the structure of the technological marketplace brought about by the availability of both converters and computers as true components.

The current edition reflects the advances in technology that have led to an explosion in the use of converters and the tremendous variety of available converters that have appeared during the recent octennium.

Not only are more converters with increasingly improved performance available in monolithic form at rapidly decreasing prices, but, as a result of improvements in monolithic and hybrid circuit technologies, uses are burgeoning for such types as high-resolution video converters, which for years had been considered by many to be expensive laboratory curiosities.

Other major advances in conversion have occurred in level of data-acquisition system integration, to match corresponding advances in processing and memory. Complete data acquisition systems are becoming available in monolithic chip form, and giant steps have been made in remote data acquisition, permitting comprehensive intelligent interfaces between sensors and host computers.

It is probably not surprising that the basic principles have changed but little; on the other hand, it has been rewarding to observe that many application examples, described tentatively and prophetically in earlier editions, are now pretty much "old hat," and can be found, described in variety and depth, in a list of publications (many with then unknown names) that seems to grow at an uncontrollably explosive rate.

In this edition, we have retained the core of useful basic information and restored such invaluable features as the "Guide for the Troubled," the Bibliography, and the Index, which were omitted in the abbreviated 1977 "Notes" edition. Besides bringing all references to the design and application of available conventional conversion products up to date, we have added chapters on video conversion, synchro and resolver converters, analog-to-frequency converters, and intentionally nonlinear converters.

To hold this book to manageable size, however, some topics, which were treated in depth in earlier editions—including especially those that comprise the all-important field of analog signal conditioning—have been elevated to independent book-length treatment and have been published by us as the

As with previous editions, it is our hope that this volume will successfully bridge the gap between the practicing engineer and the computer scientist, providing each with the complementary knowledge that will make possible a wider range of better designs for digital handling of real-world (analog) signals in this computer age. At the same time, we hope that the exposition of basic notions, the sampling of applications, and the descriptions of the wide variety of options for the interface will make the book equally attractive to teachers and students of modern electronic system practice.

We will always welcome the comments and suggestions of our readers for the benefit of the readers of future editions.

ACKNOWLEDGEMENTS

Contributions to this book have come from engineers in many departments of Analog Devices throughout the world, engaged in activities ranging from the design of monolithic integrated-circuit chips to the marketing of sophisticated high-level integrated systems for measurement, control, and test. It is one of the misfortunes of rapid growth that, while it was possible in the first edition to identify just about everyone who participated by name, it is impracticable to do so in the present volume because of the real danger of inadvertently omitting the names of many persons who have made significant contributions.

Nevertheless, the book would be incomplete without an expression of appreciation to a number of persons whose help was indispensable.

To begin with, much of the material in the first edition—especially in Part I—was so fundamental or universal in nature that it has survived with little change to benefit today’s readers. Principal contributors to that volume included Walter Borlase, Cy Brown, Lew Counts, Bob Craven, Dick Ferrero, Stan Froud, Marty Gross, Barry Hilton, Mike Lindheimer, Wayne Marshall, Jim Maxwell, Frank McCormack, Berry Phillips, Al Sanchez, Rick Spofford, Dwight Wahr, Ivar Wold, and C. Peter Zicko.

New or heavily rewritten chapters of the present volume were spearheaded by Doug Grant (Chapter 8), A. Paul Brokaw (Chapter 9), Bruce Amazeen, Bruce Coleman, and Gerard T. Quilligan (Chapter 10), Stan Domanski (Chapters 11 and 12), Dale Zeskind (with Walter Kester and Don Brockman, Chapter 13—and Ed Friedman and Geoff Boyes, Chapter 14), Larry DeVito (Chapter 15), John Wynne (Chapter 16), John Sylvan and Scott Wayne (Chapter 17), David Duff (Chapter 18), Elwyn Davies (Chapter 19), Mike Stefani (Chapter 20), and Ted Dintersmith (Chapter 21).
Substantial input, comments, and reviews came from all sides; just to name a few: Al Haun, Lisa Herbst, Steve Miller, John Mills, Jerry Neal, Rowan O’Riley, John Reidy, Al Ryan, Bill Schweber, Jim Surber, Don Travers, Russ VerNooy, Jerry Whitmore, Scott Wurcer. Feedback from numerous readers of earlier volumes was also useful. Encouragement, when needed, was provided at various times by Jim Fishbeck and Eric Janson.

The book was typeset by Joan Costa and Terri Dalton; the drawings were skillfully rendered by Ernie Lehtonen, Wendy Sheehan, and other members of the Analog Devices Publications Department, under the direction of Marie Etchells. Shelley Cohane designed the cover.

All of the above—as well as others too numerous to mention—contributed to the book’s strengths and are responsible for any success it may achieve. Any weaknesses are the responsibility of the undersigned.

_D. H. Sheingold_

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