

W.A. Kester

ANALOG DEVICES TECHNICAL HANDBOOKS

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Nonlinear Circuits Handbook

Transducer Interfacing Handbook

Synchro & Resolver Conversion

ANALOG-DIGITAL CONVERSION HANDBOOK

by
The Engineering Staff of
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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

Transducer Interfacing Handbook (1980), the *Nonlinear Circuits Handbook* (1974), and *Synchro & Resolver Conversion* (1980).

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.

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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).

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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

Norwood, Mass.