TRANSDUCER INTERFACING HANDBOOK

Analog Devices Technical Handbooks

Sheingold, ed.: Analog-Digital Conversion Handbook, 1972
(Out of Print)
Sheingold, ed.: Nonlinear Circuits Handbook, 1974
Burton and Dexter: Microprocessor Systems Handbook, 1977
Sheingold, ed.: Analog-Digital Conversion Notes, 1977
Sheingold, ed.: Transducer Interfacing Handbook, 1980
Boyes, ed.: Synchro and Resolver Conversion, 1980

TRANSDUCER INTERFACING HANDBOOK

A GUIDE TO
ANALOG SIGNAL CONDITIONING

Edited By
Daniel H. Sheingold

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PREFACE

In a continuing trend, there is an increasing use of measurement and control in Industry to improve efficiencies and reduce costs: environmental, economic, and energy-related. The *transducer* is an essential link in such a process. This book is about the electrical aspects of commonly used transducers that sense temperature, pressure, force, level, and flow.

Input transducers interface with electrical systems to provide electrical outputs that are indicative of the state of the phenomena being sensed. Usually, certain kinds of electrical interfacing processes are required, in order to provide analog information that is conveniently usable by the system. Such *signal conditioning* includes providing excitation, amplifying, filtering, linearizing, isolating, and offsetting.

This book is about the interfacing of transducers to electrical analog circuitry in preparation for readout, further analog transmission or processing, or conversion to digital form. It deals with the signal conditioning required to excite some of the most commonly used physical-to-electrical (*input*) transducers, e.g., thermistors, RTD's, strain gages, and to amplify and normalize their outputs. The book's objective is to fill the information gap that may exist between competent specialists on both sides of the interface.

Who was the book written for? One reader who might benefit is the electrical systems engineer, with a solid background in digital hardware and software, who must apply this knowledge to the measurement and control of physical phenomena via the inevitable analog signals that they spawn. Another is the mechanical engineer or physicist, who has a deep knowledge of the systems (s)he is measuring and controlling, enough electronics and good sense *not* to want to become an expert electronic designer, and a desire to know some practical options for a solution to the instrumentation problem. Then there are: those who are somewhere between the two poles; students with expectations of some day having similar needs (in thesis projects or in their working careers); the instructors who teach these students; and—finally—anyone interested in learning about practical approaches to the electrical aspects of solving measurement problems.

The text provides technical information essential for an informed "make-or-buy" electrical-interface-circuit decision. In the process,

it describes nearly one hundred applications, including some specialized complete measurement-and-control systems that have been designed and built using basic interface circuitry and standard transducers. The viewpoint throughout is that of the practical scientist, engineer, or technician; profligate use of mathematics is avoided.

We have intentionally limited the scope of the book. In order for a book on transducers to do full justice to the subject, it would have to be at least an order of magnitude larger than the present volume; yet ninety percent of the information it contained would be of use to only ten percent of its readers. When planning this book, we decided to substitute for a doctrinnaire thoroughness a useful *concentration* on those topics that have the strongest economic impact on the largest body of present and potential transducer users. The term "economic" refers to costs and benefits, measured not only in money, but also in the *time* of the busy and hard-pressed systems engineer.

Consequently, this book is principally about commonly used transducers that sense *temperature*, *pressure*, *force*, *level*, and *flow*. A large number of eminently worthy, useful, and occasionally fascinating phenomena, and their related sensors, which do not have as widespread application, have (sometimes regretfully) been omitted; examples of these include photometry and acoustic and infra-red thermometry. We have also chosen not to include position and velocity, even though our line of resolver- and synchro-digital conversion interface products is uppermost in our thoughts for many such applications.*

In addition, we have chosen to avoid discussing certain specialized transducers that are almost always purchased with matching interface electronics, usually furnished by a transducer's manufacturer. Examples include linear variable differential transformers (LVDT's), pH probes, and some capacitive transducers. In such cases, information of the kind provided here would be at once insufficient and (paradoxically) superfluous.

Finally, this book avoids the detailed consideration of interfacing in the *physical* realm. Such important particulars are in many cases an integral part of the user's expertise, and they are often

*For in-depth background on synchros and resolvers in positional measurements, the 208-page book, *Synchro and Resolver Conversion,* edited by Geoff Boyes, has just been published (1980) and is available from Analog Devices at reasonable cost.

addressed in substantial detail by sensor manufacturers. Our concentration on the *electrical* interface is in harmony with our specialization in the manufacture of electronic products for precision measurement and control. It is in this area that our readers receive the most benefit—benefits that we share, and the best of reasons for producing such a book as this.

ACKNOWLEDGEMENTS

The idea of publishing a handbook on signal conditioning for transducers was first suggested by Jim Williams. This book draws heavily from a manuscript that he wrote for us, based on his extensive experience in marrying electronic circuits with physical phenomena and his copious files of working measurement-and-control circuits that use transducers.

A great many technical and strategic ideas, an endless flow of transducer product information, and helpful chapter-by-chapter review and critique were provided by Frank Goodenough. Sanction for the book and a number of cogent suggestions that provided a basis for making the difficult decisions as to what to include and what to leave out, as well as encouragement when the going got sticky, were furnished by Bob Boole.

Contributions on technical matters came from every quarter of Analog Devices, both directly and via the already documented contributions in our literature. Though it is difficult to single out specific contributors, valuable comments directly affecting the content and organization of the book were received from George Reichenbacher and Janusz Kobel. Lew Counts and Jeff Riskin have reviewed the entire manuscript and provided valuable (sometimes pungent) comments. Portions of the book have been reviewed by Mike Timko, Jim Maxwell, and others.

By the time this book has been published, some of the chapters may have appeared in the trade press. Eric Janson will have been the interface, performing any needed excitation and signal conditioning.

The book was produced in our Publications Department, under the direction of Marie Etchells. Kathy Hurd and Joan Costa composed the type, Ernie Lehtonen, Dianne Nemiccolo, and Jean

Ellard did the drawings and mechanical layouts, and it was printed at Banta Press. The book is made available through our Literature Fulfillment and Distribution group, under Cammy O'Brien.

Much patience was asked of and unstintingly furnished by my wife, Ann, and my children.

If the book (the first of its kind that we are aware of) turns out to be as valuable a contribution as we had hoped, all of the above deserve the major share of the recognition.

Daniel H. Sheingold

Norwood, Mass.
January 2, 1980

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