APPENDIX

BIBLIOGRAPHY

The references listed here have appeared in the form of books, manuals, brochures, and articles in technical publications. Individual items have been selected because of their general or specific interest, or because they “fan out” through additional references not included here.

The list is representative rather than comprehensive and is heavily weighted in favor of recently-published material (’70’s). In most cases, the practical has been preferred to the theoretical. Within each subject grouping, the titles are listed alphabetically.

The interested reader should, in any event, seek to obtain catalogs and application notes (often voluminous) from manufacturers of the nonlinear devices of interest. Lists of current manufacturers, their products, and their addresses, will be found in such industry guides as EEM and the Electronics Buyer’s Guide. Since the technology is rapidly expanding (and changing), one should also seek to be placed on manufacturers’ mailing lists, and to subscribe to at least one of the major semimonthly electronics industry technical periodicals to keep up with new products, new techniques, and new literature.

Readers of this book are invited to subscribe to Analog Dialogue, which appears (approximately) quarterly, and is available at no charge from Analog Devices, Inc. Other publications available are the most recent edition of the Analog Devices Product Guide, data sheets on individual products, and occasional “Application Notes” on topics of interest.

Copies of certain publications mentioned in this Bibliography, designated by an asterisk (*), are also available upon request (free, except for the A-D Conversion Handbook) as of the time this book has gone to press. They will be available as long as the supply lasts. Except for these items, no other publications mentioned here are available from Analog Devices.

LINEAR AND NONLINEAR CIRCUITS, GENERAL INFORMATION


FUNCTION FITTING


TIME-FUNCTION GENERATION


“Analog-to-Pulse-Width Converter Yields 0.1% Accuracy,” N. Robin, EDN, November 1, 1970.


*Data Sheets, Models 350, AD351 Comparators, Analog Devices.


"Triangular and Square-Wave Generator has Wide Range," R. Burwen, EDN, December 1, 1972.


**INSTRUMENTATION AND MEASUREMENT**


**SIGNAL PROCESSING**


**COMPUTING AND CONTROL**


**LOG, LOG RATIO, AND ANTILOG CIRCUITS**


MULTIPLIERS AND DIVIDERS


"Characteristics and Applications of Modular Analog Multipliers,” E. Zuch, Electronic Instrumentation Digest, April 1969.


"Don’t be Fooled by Multiplier Specs,” R. Stata, Electronic Design, 6, March 15, 1971.


"In IC Form, Hall-Effect Devices Can Take on Many New Applications,” M. Oppenheimer, Electronics, August 2, 1971.


**PIECEWISE-LINEAR APPROXIMATIONS, POWERS & ROOTS, MISCELLANEOUS**


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