ELECTRONIC CIRCUIT THEORY

Devices, Models, and Circuits

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TO

PRISCILLA AND JEANIE

FOREWORD

This book is one of several resulting from a recent revision of the Electrical Engineering Course at The Massachusetts Institute of Technology. The books have the general format of texts and are being used as such. However, they might well be described as reports on a research program aimed at the evolution of an undergraduate core curriculum in Electrical Engineering that will form a basis for a continuing career in a field that is ever-changing.

The development of an educational program in Electrical Engineering to keep pace with the changes in technology is not a new endeavor at The Massachusetts Institute of Technology. In the early 1930's, the Faculty of the Department undertook a major review and reassessment of its program. By 1940, a series of new courses had been evolved, and resulted in the publication of four related books.

The new technology that appeared during World War II brought great change to the field of Electrical Engineering. In recognition of this fact, the Faculty of the Department undertook another reassessment of its program. By about 1952, a pattern for a curriculum had been evolved and its implementation was initiated with a high degree of enthusiasm and vigor.

The new curriculum subordinates option structures built around areas of industrial practice in favor of a common core that provides a broad base for the engineering applications of the sciences. This core structure includes a newly developed laboratory program which stresses the role of experimentation and its relation to theoretical model-making in the solution of engineering problems. Faced with the time limitation of a four-year program for the Bachelor's degree, the entire core curriculum gives priority to basic principles and methods of analysis rather than to the presentation of current technology.

J. A. STRATTON

P R E F A C E

The importance of electronic devices, circuits, and systems in modern technology is apparent to most electrical engineering students; many have acquired practical experience with circuits before they begin formal study of the subject. Electronic circuit theory can be introduced to the student in a variety of ways. In view of the many devices available and the numerous applications of electronic circuits, it is important in any plan of presentation to seek unifying principles. Such principles permit the student to extend his knowledge in a rapidly advancing field.

We have organized our approach to electronics around circuit models and methods of circuit analysis in order to reduce the number of separate ideas and concepts. The many functions performed by electronic systems can be understood in terms of a few fundamental circuits if similarities are sought.

This book deals with electronic devices, models, basic circuits and circuit functions. Many of the interesting properties of electronic devices are a consequence of nonlinearity accompanied by regional linearity. As a result, piecewise-linear circuit models can be used to convert a nonlinear circuit problem to a number of related linear problems. Thus, the mathematics of linear circuit theory can be applied to a broad class of physical circuits and systems operating in a nonlinear manner.

The model concept emphasizes the need for making approximations as part of the process of analyzing a physical problem. The student is thus encouraged to exercise judgment in order to arrive at the simplest circuit models that will give an adequate result. Extremely

simple models can be used to explain the general mode of operation of electronic circuits. Simple resistive models together with one major energy-storage element suffice to explain the behavior of most basic circuits. Refinements in the resistive model and one or two additional energy-storage elements provide adequate accuracy for nearly all design purposes. Sinusoidal or rectangular-wave circuit response illustrates basic operations such as waveform generation, wave shaping, amplification and modulation. A companion volume presents methods of linear and quasi-linear analysis pertinent to more complicated electronic circuits, signals and systems.

The emphasis on general methods illustrated by specific examples is in keeping with the present trend in engineering education. The emphasis on fundamentals is the inevitable consequence of rapid development, particularly in such fields as electronics, communications, and computation, which have literally exploded in the past decade. In today's technology, a specialized education becomes obsolete too soon after graduation. We do not mean to say that real problems and applications should be avoided. However, too much specialization, either in fact or in attitude, deprives the student of the background and the confidence that will enable him to enter new fields. Moreover, technical problems often span several disciplines so that breadth of understanding becomes more important in the long run than detailed knowledge.

Some of the material presented in this book evolved from a graduate subject on pulse circuits, and some was developed during the revision of the introductory undergraduate subject on electronic circuits (part of the core curriculum for all electrical engineering students at M.I.T.). With minor variations, portions of the material in this book have been used for five years in this core subject.

The development of this presentation of electronic-circuit theory was influenced by the early work of Godfrey T. Coate. Contributions have also been made by other colleagues on the teaching staff; in particular, many of the problems were prepared by section instructors. Ideas have come from staff members of the Research Laboratory of Electronics or have resulted from the stimulation of the research environment. The inspiring leadership of Professor Ernst A. Guillemin in circuit theory research and teaching has had both tangible and intangible effects on the project. Many worth-while suggestions have been made by our students.

During the final stages of the book, we had the invaluable aid of Professor Campbell L. Searle, whose critical technical editing contributed greatly to the improvement of the manuscript. In addition,

he gave his time and effort unsparingly to galley reading in order to help us meet publication deadlines. As in any other book, a number of errors inevitably remain. The number would have been greater had it not been for the perceptive checking and page proofing done by Professor Richard D. Thornton, who also took major responsibility for organizing the index.

We are most grateful to Professor Gordon S. Brown for creating a departmental environment in which academic experiments are the rule rather than the exception. His constant encouragement has provided a real stimulus throughout the subject revision, note writing, manuscript, and production stages of this project.

Our acknowledgements would be incomplete without an expression of thanks to the secretaries who typed rough draft, notes, and manuscript. They are Bertha Hornby, Rosemarie Connell, Dorothea Scanlon, Marjorie D'Amato, and Louise Juliano.

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