Preface

This book is the outgrowth of a course in switching circuits that the writer has taught since 1960. The original class notes for the course were written in an attempt to provide a unified treatment of sequential circuit theory.

An effort has been made to include only those techniques that have been generally accepted and that will have lasting application. No attempt has been made to include current hardware circuit realizations since the continuous advance of technology tends to render specific hardware rapidly obsolete. Circuit realizations are considered only in terms of gate symbols.

The subject matter is organized into nine chapters, one introductory, three on combinational circuit theory, and five on sequential circuit theory.

An introduction to digital systems, number systems, and binary codes is given in Chapter 1, and Boolean algebra and switching functions along with algebraic techniques for the manipulation and minimization of the algebraic expressions are presented in Chapter 2.

Chapter 3 covers the analysis and synthesis of combinational gate circuits and includes the topic of functional completeness. The subject of threshold logic is considered in some detail. In Chapter 4 geometric and tabular techniques are presented for the minimization of algebraic expressions. These techniques are limited to two-level logic realizations since general techniques for multilevel logic realizations are not currently available.

The underlying objectives in the presentation of the material on sequential circuits are to provide a unified view of the various modes in which these circuits can be operated and to provide general techniques for their analysis and synthesis. The author believes that the former is best achieved by classifying the circuit operation as either fundamental mode or pulse mode, and as either clocked or not clocked. Both algebraic and tabular techniques are presented for the analysis and synthesis of these circuits.

The order of presentation of the sequential topics has been chosen to provide a logical sequence. Since the reader has, in his study of combinational circuit theory, become familiar with input signals whose duration in either state is not limited, it is natural to proceed first to a study of sequential circuits that operate in fundamental mode. Further, since he has thus far studied only gate circuits, it appears natural to proceed first with sequential circuits that are realized using only gate elements and where memory is achieved through feedback. The theory can then be extended to circuits that use specific memory elements (which are themselves gate circuits with feedback).

A general approach is emphasized by showing that sequential circuits designed for operation in either fundamental or pulse mode and either clocked or not clocked can each be realized either using gates alone (with the addition of suitable delays) or using a combination of gates and memory elements.

The analysis of sequential circuits is considered first and presented in Chapter 5. Although the techniques are shown explicitly for circuits that operate in fundamental mode, they apply also to circuits that operate in pulse mode. The only difference lies in the interpretation of the final table. Both algebraic and tabular techniques are introduced.

Chapter 6 is concerned with the synthesis of sequential circuits for operation in fundamental mode. Since the flow tables for such circuits are characteristically derived with redundant rows, it is desirable to reduce them before their realization is attempted, and for this reason a simplified technique for flow-table reduction is introduced at this point. Static and essential hazards are included in this chapter.

In Chapter 7 synthesis techniques are presented for circuits that operate in pulse mode. The flow table for this mode of operation is derived as a modification of the flow table for fundamental-mode operation. The motive here is to obtain a circuit design that requires fewer memory states. A comparison of the two modes of sequential circuit operation is made. The distinguishing characteristic of pulse-mode operation is stressed, and several methods are presented for obtaining this characteristic when flip-flops are used in the circuit realizations.

Chapter 8 covers the clocked or synchronous operation of sequential circuits and includes circuits for operation in both fundamental mode and pulse mode. Use of the same problem specifications enhances the comparison of circuits designed for operation in each mode; for example, the fact that circuits designed for operation in pulse mode often require fewer memory elements is clearly evident. Both algebraic and tabular design techniques are included.

A unified treatment of the two modes of sequential circuit operation is facilitated by the use of only one type of flip-flop in the presentation of the sequential theory. The type RS flip-flop is used since it is the only flip-flop in current use that can be operated unclocked in either mode. Other types of flip-flops are considered in Chapter 8 after clocked operation has been presented, and examples are given in which the flip-flop input-gating costs are compared and related to the form of the next-state equations.

Lastly, techniques are presented for the realization of sequential circuits when the circuit specifications are given in terms of control states and register transfers.

In Chapter 9 the subject of sequential circuit minimization is considered. A more general technique is presented for the reduction of flow tables, and the state-assignment problem is discussed.

The material in this book can essentially be covered in a single-semester advanced undergraduate course. Experience has shown that laboratory experimentation with switching devices provides valuable aid to the reader's understanding of the mathematical models. Answers are provided to selected problems.

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