MASSACHUSETTS INSTITUTE OF TECHNOLOGY

RADIATION LABORATORY SERIES

LOUIS N. RIDENOUR, *Editor-in-Chief*

PULSE GENERATORS

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27. COMPUTING MECHANISMS AND LINKAGES—*Svoboda*
28. INDEX—*Henney*

PULSE GENERATORS

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Foreword

THE tremendous research and development effort that went into the development of radar and related techniques during World War II resulted not only in hundreds of radar sets for military (and some for possible peacetime) use but also in a great body of information and new techniques in the electronics and high-frequency fields. Because this basic material may be of great value to science and engineering, it seemed most important to publish it as soon as security permitted.

The Radiation Laboratory of MIT, which operated under the supervision of the National Defense Research Committee, undertook the great task of preparing these volumes. The work described herein, however, is the collective result of work done at many laboratories, Army, Navy, university, and industrial, both in this country and in England, Canada, and other Dominions.

The Radiation Laboratory, once its proposals were approved and finances provided by the Office of Scientific Research and Development, chose Louis N. Ridenour as Editor-in-Chief to lead and direct the entire project. An editorial staff was then selected of those best qualified for this type of task. Finally the authors for the various volumes or chapters or sections were chosen from among those experts who were intimately familiar with the various fields, and who were able and willing to write the summaries of them. This entire staff agreed to remain at work at MIT for six months or more after the work of the Radiation Laboratory was complete. These volumes stand as a monument to this group.

These volumes serve as a memorial to the unnamed hundreds and thousands of other scientists, engineers, and others who actually carried on the research, development, and engineering work the results of which are herein described. There were so many involved in this work and they worked so closely together even though often in widely separated laboratories that it is impossible to name or even to know those who contributed to a particular idea or development. Only certain ones who wrote reports or articles have even been mentioned. But to all those who contributed in any way to this great cooperative development enterprise, both in this country and in England, these volumes are dedicated.

L. A. DUBRIDGE.

Preface

WHEN the Radiation Laboratory was organized in the fall of 1940 in order to provide the armed services with microwave radar, one of the important technical problems facing this group was that of devising equipment capable of delivering high-power pulses to the newly developed cavity-magnetron oscillator. To be sure, some techniques for generating electrical pulses were available at this time. However, the special characteristics of these magnetrons and the requirements imposed by the operation of a microwave-radar system (high pulse power, short pulse duration, and high recurrence frequency) made it evident that new techniques had to be developed.

During the existence of the Radiation Laboratory the group assigned to the problem of pulse generation grew from a nucleus of about five people to an organization of more than ten times this number. The coordinated efforts of this group extended the development of pulse generators considerably beyond the original requirement of 100-kw pulses with a duration of 1 μsec and a recurrence frequency of 1000 pps. The development extended to both higher and lower powers, longer and shorter pulses, and lower and higher recurrence frequencies. Besides the improvement of existing techniques, it was necessary to devise entirely new methods and to design new components to provide satisfactory pulse generators for radar applications. The use of a lumped-constant transmission line (line-simulating network) to generate pulses of specific pulse duration and shape was carried to a high state of development. As a result of work both on transformers that could be used for short pulses and high pulse powers and on new switching devices, highly efficient and flexible pulse generators using line-simulating networks were available at the end of the war. Concurrent with the work at the Radiation Laboratory, a large amount of work was done at similar laboratories in Great Britain, Canada, and Australia, and at many commercial laboratories in this country and abroad.

The purpose of this volume is to present the developments in the techniques of pulse generation that have resulted from this work. These techniques are by no means limited to radar applications: they may be used with loads of almost any conceivable type, and should therefore be applicable to many problems in physics and engineering. The discussion of pulse-generator design and operation is divided into three principal parts. Part I is concerned with hard-tube pulsers, which are Class *C*

amplifiers specifically designed for the production of pulses of short duration and high power; Part II presents the characteristics of the line-type pulser, which utilizes the line-simulating networks; Part III considers the design and characteristics of pulse transformers. Throughout this volume both the theoretical and the practical aspects of pulse-generator design are given in order to avoid restricting the available information to radar applications.

Although the major part of this volume is written by a few members of the Radiation Laboratory staff, many other individuals at the Radiation Laboratory and elsewhere have contributed their ideas in the preparation of this material, and we hereby acknowledge their contributions. Particular mention must be made of the work done by Miss Anna Walter in connection with many of the mathematical analyses. Her painstaking work in checking the mathematical derivations and making the long and tedious calculations necessary for many of the curves and numerical examples is gratefully acknowledged. We are glad to acknowledge also the work of Miss F. Newell Dutton, who processed the numerous pulse photographs that appear throughout the volume.

We are also indebted to the many people who have contributed their time freely in reading various chapters and sections of the manuscript, and who have made valuable suggestions for the improvement of the discussion. We wish to acknowledge the help received in this way from Mr. J. P. Hagen and his associates at the Naval Research Laboratory; Dr. J. E. Gorham and his associates at the Army Signal Corps Laboratory; Dr. F. S. Goucher, Mr. E. P. Payne, Mr. A. G. Ganz, Mr. A. D. Hasley, Mr. E. F. O'Neill, and Mr. W. C. Tinus of the Bell Telephone Laboratories; Mr. E. G. F. Arnott, Mr. R. Lee, Mr. C. C. Horstman, and Dr. S. Siegel and his associates at the Westinghouse Electric Corporation; Mr. H. W. Lord of the General Electric Company; Dr. A. E. Whitford of the Radiation Laboratory and the University of Wisconsin; and Dr. P. D. Crout of the Massachusetts Institute of Technology.

The preparation of the manuscript and the illustrations for this volume would have required a much longer time if we had not had the aid of the Production Department of the Office of Publications of the Radiation Laboratories. We wish to express our appreciation of the efforts of Mr. C. Newton, head of this department, for his help in getting the work done promptly and accurately.

THE AUTHORS.

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Contents