STORAGE TUBES

and Their Basic Principles

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PREFACE

Although the importance of electronic storage for television, computer, and signal-converter applications is generally recognized, and a number of books exist which treat this subject, no previous textbook has been primarily concerned with storage tubes. It is the purpose of this book to explain in concise form the fundamental operation of the different types of storage tubes and to provide this information in an easily accessible manner.

During the evolution of the manuscript it became more and more apparent that the operation of charge-controlled storage tubes could in general be explained on a common basis of relatively few fundamental processes of writing and reading. It is believed that this approach facilitates the understanding of the mechanism of such devices and should make the book useful both to electronic engineers and to teachers or students interested in this general subject.

In the text the different storage tubes have been described with many minor details omitted. This has been done for the sake of emphasizing the fundamental storage principles. It is hoped that the reader will refer to the bibliography (Part VIII) for additional details.

Many of the storage tubes described are still in the development stages. Since their uses and applications have not yet been fully explored and they are still subject to modifications, no attempt has been made to compare the properties of similar types of tubes quantitatively.

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INTRODUCTION

Charge-controlled storage tubes have been employed as television-camera tubes since the early days of television. Since about 1940 they have also become increasingly important as devices for signal conversion, direct viewing, and computing applications. Since the storage of information in such tubes depends neither on mechanical movements nor on physicochemical changes in a material, but on the establishing or removing of minute electrical charges on an insulating surface (or array of insulated elements), the speed of operation is very high. In practical tubes the amount of electrical charge stored per target element is in the order of 10^{-11} coulombs or less, thus permitting time-varying electrical information to be stored on (or removed from) successive elements at rates as high as a few megacycles per second.

Because of the fact that a pattern of electric charges corresponding to the light and dark areas of a visual picture can be established on the storage surface, the storage tube has found its most extensive use in television applications, especially in the field of pickup tubes which convert visual to electrical signals. For these types of applications storage tubes such as the Iconoscope and Image Orthicon have been furthest developed.

In the transmission of picture information it is frequently necessary to change from one type of scanning to another such as radial scanning (P.P.I.) to rectangular scanning (raster), or to change the frame frequency of transmitted electrical information in coordinating, for example, one television system with another. For these purposes the frequency-converter type of storage tube is very useful. It is also important in applications involving integration for increasing the signal-to-noise ratio, and the recording of single transients from which it is desired to produce a number of copies. Considerable developmental work has already been accomplished on several of these devices, with many new applications expected.

Where the direct viewing of visual patterns or pictures is concerned, charge-controlled viewing storage tubes, although not as fully developed as the other types above, are expected to play an important part in applications where, for example, it is desired to view a short electrical transient signal for a long period with little decay, where it is desired to control the decay of a stored signal, where higher light output is desired than can conveniently be obtained with ordinary scanning types of cathode-ray tubes, or where low frame repetition rates are desired without flicker.

Charge-controlled storage tubes have also become important as essential components in computing devices. Because of the rapidity with which electrical information can be stored at an arbitrary target element (time durations as short as a few microseconds) storage tubes are finding one of their most important uses where complex operations require rapid storage of intermediary information and rapid access to this information. For computing applications several successful types of tubes have already been designed, with additional development work continuing.

The operating mechanism of storage tubes is largely dependent on the control of secondary-emission currents from an insulating target and bombardment-conductivity currents through the target material. In Part I the equilibrium potentials acquired by insulated elements under steady electron bombardment are discussed. On the basis of this discussion and the definitions of Part II the various methods of establishing a charge pattern by dynamically controlling the secondary emission and bombardment conductivity are then described in Part III. A more complete understanding of secondary emission itself may be obtained from the literature indicated in Part A of the bibliography. In particular, the works of Bruining (Ref. 2) and McKay (Ref. 9) provide relatively complete surveys of the secondary emission of both insulators and metals.

In addition to secondary emission and bombardment conductivity, the processes of photoemission and photoconductivity play an important role in the charging action of television camera tubes. These charging actions are therefore also discussed in the above-mentioned parts from the static and dynamic viewpoints.

The following Parts, IV, V, VI, and VII, are devoted to a discussion of the various types of storage tubes. Although these tubes have been grouped into parts on the basis of their general application, such as signal conversion or computing, it is also believed desirable to classify the tubes (a) by the method of applying the input signal (cathode modulation or backplate modulation, for example), since it most clearly differentiates the tubes on the basis of their circuit operation, and (b) by the basic writing and reading mechanisms which take place within the tubes.

It should be noted that in a number of cases the physical construction of a tube permits it either to be employed for a different application or to operate with a different writing and reading mechanism than indicated in the following text. However, individual storage tubes have usually been designed with a particular application and type of operation in mind so that numerous design considerations incorporated in their structure, such as target thickness, target leakage, secondary-emission properties of the target, collector geometry, and beam current and voltage as required by electron-optical considerations, frequently limit the practical employment of individual tubes differently than intended by the original design.

In the following sections simplified diagrams which indicate only the essential components of each tube are employed, so that the mechanism of operation can be most clearly explained. For the purpose of discussing the operation of the tubes on a common basis related to Parts I, II, and III each tube is described with the collector electrode connected to ground directly or through an output resistor. Although in the reference literature the electrode which is grounded may vary from tube to tube, the assumption of a grounded collector does not change the basic operation.

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