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Elements of Electronics

for physical scientists

R. L. HAVILL and A. K. WALTON

Department of Physics, University of Sheffield

Second Edition

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Preface to First Edition

The growth of electronics during the past three decades has been prolific. There have been far-reaching social and domestic repercussions and the adoption of electronic techniques by scientists has become commonplace. This book is intended to provide an introductory course for students who are at about first or second-year University level but are not specialising in electronics. It has been written primarily with physical scientists in mind and a corresponding knowledge of physics and mathematics is taken for granted. In particular, familiarity with alternating-current theory including important network ideas such as that embodied in Thévenin's theorem is assumed and an acquaintance with quantum ideas and electromagnetic theory is expected.

The interest of physical scientists in electronics is twofold. Firstly, there is a desire to understand and apply relevant electronic circuits to facilitate the execution of experiments. Secondly, there is a wish to understand the physical operation of the active devices involved. In writing a book it is difficult to strike a balance between these objectives. The authors have chosen to bias the contents of this volume in the direction of circuit electronics in the belief that this represents the greater interest of the majority of scientists in electronics. Emphasis is placed on understanding and designing basic circuits rather than complete systems, although this important topic is broached near the end of the book. The authors are also of the opinion that beginners are generally overwhelmed by large textbooks and the present text has therefore been restricted to about 300 pages. Sufficient physical theory for introductory purposes is presented in just three chapters. Within the limited space, a simple explanation of as wide a variety of devices and electronic methods as possible has been considered to be more important than a detailed treatment of any particular topic. Accordingly, it has not been possible to develop some aspects of the subject to what might be termed a 'professional level'.

A decision to develop the theory of electronic circuits in terms of the bipolar transistor was taken for the following reasons. Development of electronic theory in terms of more than one device at a time often leads to confusion and is

wasteful in space. At present, the bipolar transistor is by far the most widely used discrete component. It has a more general low-frequency equivalent circuit than other active devices such as the field-effect transistor or the thermionic valve and is clearly the most sensible choice. In view of this approach, thermionic valves and field-effect transistors and their circuits are discussed in a separate chapter.

Despite the fact that integrated circuits are coming into widespread use, attention has been concentrated on circuits built from discrete components since the prime concern of this book is to explain the action of basic circuits. Consideration of integrated circuits adds nothing to basic understanding; they are essentially a matter of detailed technology. It has been thought worth while, however, to draw attention to a few particular integrated circuits in relevant parts of the text and to outline their method of fabrication.

Above all else, electronics is a practical subject and it is vital that in parallel with any theoretical study, practical experience is gained by investigating real devices and by building, testing and measuring the properties of real circuits. Discrete components such as transistors, resistors and capacitors are essential for this purpose. A series of laboratory exercises has been devised and it is suggested that these are followed in *parallel* with reading the theoretical chapters. Solutions to and comments on these exercises are provided. The very first exercise on R-C networks should reveal the advantage of a laboratory approach to learning the subject. Laboratory work should *not* be a minor adjunct to theoretical study; it is crucially important in its own right. In the physics department at Sheffield University the exercises occupy about thirty laboratory periods of three hours each, while the theoretical chapters are covered in about forty lectures.

In the interest of clarity, some circuits in the text have been simplified. Often the simplification is just the adoption of simple biasing rather than a stabilised arrangement. Such simplifications are pointed out throughout the text.

We would like to acknowledge the provision of facilities in the physics department at Sheffield, not to mention the unwitting co-operation of undergraduate students, both of which have been invaluable in developing the laboratory exercises. Particular thanks are due to Mrs L. Ottiwell and Mrs J. S. P. Appleby for their assistance with the preparation of the figures and manuscript.

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1975*

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Preface to Second Edition

Since publication of the first edition, electronics has continued to evolve explosively, mainly as a result of the continual improvement and increased application of integrated circuits. Notwithstanding the chip revolution, the authors still believe that basic electronics is best taught through circuits built from discrete components so that their design and operation can be thoroughly studied. The second edition consequently retains the initial development of the key electronic functions of linear application and switching in terms of the junction transistor. However, the early chapters now lead on to integrated-circuit forms of amplifiers, oscillators and logic, reflecting current practice. Much of the middle of the book has been rewritten to this end. In particular, the chapter on 'Digital Logic' is extensively revised and extended while a new chapter on 'Integrated-circuit Technology' has been added. It has also proved beneficial to regroup the topics of feedback and d.c. amplification into three chapters, namely 'Feedback', 'D.C. Amplification and Operational Amplifiers' and 'Sinusoidal Oscillators'.

While updating and re-organising the second edition, the opportunity has been taken to strengthen several areas. For example, a much better treatment of the high-frequency behaviour of transistors is presented and a more general view of feedback is offered. Operational amplifiers are afforded much greater coverage, more extensive quantitative physical theories of the JFET and MOSFET are introduced and Thévenin's theorem is included as an appendix. The rapidly developing field of optoelectronics now merits a separate chapter and a greater variety of systems is considered in the concluding theoretical chapter.

To match the increased content, the number of laboratory exercises has been increased from 19 to 25. However, throughout the revision, the need to keep the length of the text within reasonable bounds has been constantly borne in mind, as has the objective of as wide a coverage of topics as possible. Sections that could be omitted on the first reading without compromising development of basic understanding are marked with a single asterisk or a double asterisk when also rather difficult.

Provision of facilities in the physics department at Sheffield is again gratefully acknowledged. In particular, we are indebted to Mr J. C. Newell for occasional help with circuit testing and to Mrs K. Batty and Mrs S. Stapleton for their considerable assistance in preparing the figures and manuscript.

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