A PROGRAMMED COURSE IN

basic transistors

NEW YORK INSTITUTE OF TECHNOLOGY

A PROGRAMMED COURSE IN

BASIC TRANSISTORS

THE STAFF OF ELECTRICAL TECHNOLOGY DEPARTMENT
NEW YORK INSTITUTE OF TECHNOLOGY
ALEXANDER SCHURE, Project Director

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OTHER BOOKS PREPARED BY THE STAFF OF
NEW YORK INSTITUTE OF TECHNOLOGY

- A PROGRAMMED COURSE IN
  BASIC ELECTRICITY
- A PROGRAMMED COURSE IN
  BASIC ELECTRONICS

Preface

The programmed course in basic transistors contained in this book continues a tested procedure for taking firm steps toward electronic specialization. Starting with the assumption that the student has a background in the fundamentals of electricity and electronics, this course develops the basic electrical concepts related to transistors that are essential to later studies in electronics. The carefully organized logical sequence of interrelated steps permits the student to proceed at a pace best suited to his abilities and needs. He is constantly aware of his progress by means of immediate feedback as well as many checks and repetitions. He is his own tutor and his own examiner. Visual instruction is aided by clear, uncomplicated diagrams. Mathematics has been kept at a minimum, especially in the earlier sections of the work, to enable the nonmathematically minded reader to achieve a firm grasp of the necessary concepts.

There is one major prerequisite for the successful completion of this course: *interest*. An inner drive to learn is often a more important ingredient than a high I.Q. Armed with determination and perseverance, the man with a strong desire to learn simply cannot fail.

The text is designed for an introductory one-semester course; it is preceded by two additional texts, also in linear programmed form: *A Programmed Course in Basic Electricity* and *A Programmed Course in Basic Electronics*. Each may be used independently, or the three may be studied in sequence.

The three books had their beginnings in 1958. At that time, faculty members of the electrical technology department of New York Institute of Technology undertook the development of an integrated series of programmed learning materials relating to electronics. In conferences held with training directors and curriculum specialists, an agreement was reached on the topics comprising those segments of electronic training considered essential in the majority of industrial and formal educational programs. The conferees further agreed that variations in background would require structuring the programs on several levels, with one major program being fundamental in approach. The overall project was termed the PRINCE Project (*P*rogrammed *R*einforced *I*nstruction *N*ecessary to *C*ontinuing *E*ducation). This volume is part of the series dealing with the *basics* of electricity, electronics, semiconductors, transistors, and pulse circuits.

By early 1961, preliminary versions of the programs had been prepared and tested by the programming teams. The next step required extensive field testing under various instructional conditions. In May of 1961, the Institute requested the assistance of the Educational Coordinating Committee of the Electronics Industries Association, offering the developed programs to industry on a cooperative data-exchange basis. Participating companies were asked to make their test data available for use in refining, revision, and developing a validated teaching instrument. Through the efforts of the committee, and through the interest of other industrial groups, a number of companies became aware of the project and agreed to aid in the validation. Among these companies were:

Aerovox Corporation, *New Bedford, Massachusetts*
The Boeing Company, *Renton, Washington*
Corning Glass Works, *Corning, New York*
E. I. DuPont de Nemours & Company, *Wilmington, Delaware*
Eastman Kodak Company, *Rochester, New York*
General Dynamics/Pomona, *Pomona, California*
General Electric Company, *Philadelphia, Pennsylvania*
Hycon Manufacturing Company, *Monrovia, California*
International Telephone and Telegraph, *Belleville, New Jersey*
Lockheed Aircraft Corporation, Missiles and Space Division, *Sunnyvale, California*
McDonnell Aircraft Corporation, *Saint Louis, Missouri*

Concurrent with the industrial validation, a validation program in a number of technical institutes and community colleges was undertaken with the cooperation of McGraw-Hill, Inc. Thus, all material was thoroughly tested in the preliminary version titled *Basic Transistors.*

The data gathered from these exchanges were returned to the programming teams as the study progressed. Revisions were then made and the restructured programs retested and put in final form.

Grateful acknowledgment is hereby extended to the General Electric Company for its permission to reproduce illustrations and curves from the 6th edition of the General Electric Transistor Manual for this programmed work; to Benjamin Edelman of Western Electric, Chairman of the Educational Coordinating Committee of the Electronics Industry Association; George Maedel of RCA, Chairman of the Curriculum Development Task Force of EIA during the major portion of this study; the training directors of the participating companies; the programming teams and faculty of New York Institute of Technology; and the many others who, through their efforts, brought this project to fruition.

ALEXANDER SCHURE

To the User

Programmed instruction

No matter how deeply you probe the nature of electronics, you will always be dealing with certain basic principles. The understanding necessary to become an electronics technician comes from a grasp of the fundamental concepts of electricity.

As your skill in electronics grows, you will realize how important these basic ideas are. To understand the complex, you should know about the simple. Much of this basic information is in the program which follows.

The information in this course is organized in a relatively new manner. As you work with the materials in the lessons that follow, you will find that the information you are asked to learn has been arranged to provide for your participation in the instruction. This method of teaching is called *programmed learning.*

In presenting the information, the subject matter is divided into small units called frames. Most of the time, each frame requires that the statement in the frame be completed. With a little thought you should be able to provide the correct answer, or response. The correct answer is enclosed in parentheses and appears at the beginning of the frame which follows. You should look at the correct answer only after you have written what you feel to be the proper one.

In order to introduce you to this method, the following section is programmed. Cover the answers with a cardboard or paper sheet. Lower the sheet only *after* you have written your answer. Use reasonable judgment to decide whether your response is the same as the printed answer. Now try the sample frames which follow.

---

1. Self-instructional materials will be given to you in the same form as the frames which follow. Your first feelings may be that you are taking a test. You are not! Understand this clearly—programmed learning is a teaching method and is much more than just a t______________. (Complete the statement.)

---

2. (test) The purpose of this book is *to teach you* in just the same way as if you were receiving individual instruction. So, your self-instructional text, called a program, acts as your private teacher. We can now say: A self-instructional book is called a p______________.

---

3. (program) A program presents the information to be learned in small bits, a few sentences at a time. You will either complete a statement, find information on a diagram, or make a choice. For example, you might be asked to complete this statement:

What you learn from each frame of this program will not be graded because the program is a (test, teaching device).

---

4. (teaching device) Let's move on now. We've said the program presents information in small amounts at a time. These small segments are called frames. Each numbered statement in the program is a frame.

This is the fourth ______________ in this series.

---

5. (frame) Thus, we see each frame leads us further into the subject by giving a little additional information or by searching for information learned in that frame or a previous one. After receiving this information, you check the next frame to determine, immediately, if you are ______________.

---

5. (correct)

Information Panel

Some frames or chapter introductions give you information and do not ask you to make a response. Information and summaries given in this way are important. Read them carefully. Then, just go on to the next frame. Do so now.

---

6. Let's summarize: Programmed learning involves breaking up the subject matter into small units, called ______________.

---

7. (frames) Each frame will require a(n) ______________ from you.

---

8. (response *or* answer) In the frame below, you will find the correct ______________.

---

9. (response *or* answer) From time to time you will be given supplementary material in the form of problems and exercises. You will be required to do these ______________ and ______________.

---

10. (problems, exercises) Proceed at the rate best suited to you. One of the great advantages of programmed material is that each student can proceed at his own ______________.

---

11. (rate *or* pace) Because you are working at your own rate, there will be no ______________ limit for your completion of "daily lessons."

---

12. (time) Remember the difference between the words teach and learn. The program will teach, but only you, the ______________, can learn.

---

13. (student) You must, therefore, make the effort to ______________ from the program.

---

14. (learn) No matter how a course is taught, the responsibility for learning is with you, the ______________.

---

15. (student) The program is a teaching device and not a ______________. Since this is so, there is no reason to look ahead for an answer. If you do so, you will merely be cheating yourself of the opportunity of *le__ing.*

---

16. (test, learning) Extra *learning* steps are built into the program. Completion summaries and check quizzes will help you ______________.

---

17. (learn) You are to complete each of these self tests. Be sure to answer every question. You may then compare your answer with the ______________ answer shown.

---

18. (correct) Remember, when you reach the c_____tion summaries, you are to fill them in and check your answers. You are also required to answer all the questions in the ______________ quizzes.

---

18. (completion, check)

You are now ready to proceed with the program.

Voltage, Current, and Power Symbols (IEEE Standards)

ELECTRICAL QUANTITIES	EXAMPLES
BASE LETTERS:	
Instantaneous values, which vary with time, are represented by lowercase letters	i, v, p
Average (d-c) and RMS values are represented by capital letters	I, V, P
SUBSCRIPTS:	
D-c and instantaneous total values are indicated by capital-letter subscripts	i_E, I_E, V_{CB}
Varying component values are indicated by lowercase subscripts	i_e, I_e, v_{eb}
SUBSCRIPT REFERENCE:	
Base electrode	B, b
Collector electrode	C, c
Emitter electrode	E, e

SYMBOLS

SUBSCRIPTS	i, v, p	I, V, P
b c e	Instantaneous varying component value	RMS or effective varying component value
B C E	Instantaneous total value	Average (d-c) value

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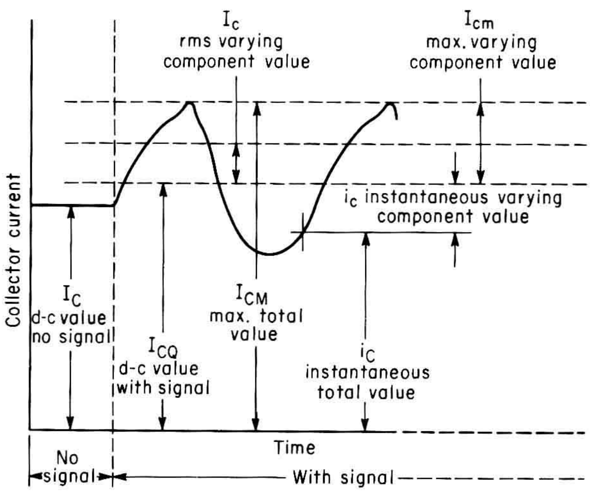

Illustration of proper symbol usage

Contents

CHAPTER 1 Semiconductor Fundamentals

Introduction

1 • 1 A triode vacuum tube is a "valve" in which the flow of electrons is controlled by voltages between grid and cathode. A transistor is also a "valve" in the same sense as a triode. In the transistor, the flow of ______________ and other "current carriers" is also controlled.

1 • 2 (electrons) A triode depends upon the flow of current carriers (electrons) through a near vacuum inside the tube envelope. In a transistor, the flow of current carriers occurs in a material known as a "semiconductor" rather than in a ________ as in the triode.

1 • 3 (vacuum) The transistor's ability to control __________ carriers makes it potentially the most useful single element in modern signal communications and entertainment equipment.

1 • 4 (current) In increasing numbers, ______________ are being applied in military radio, sound, radar, facsimile, telephone, teletypewriter, and computer assemblies.

1 • 5 (transistors) The first semiconductor "crystals" to be used in radio appeared in early receivers where they were used to recover the audio-frequency component from a received carrier. Thus, the first use for semiconductor crystals was that of demodulation or ______________ of an AM signal.

1 • 6 (detection or rectification, etc.) In these early "crystal sets," the semiconductor material was usually lead sulfide or galena. A galena-metal interface has the property of high resistance for one direction of current flow and low resistance for the other. Thus, a galena crystal can be used to perform the function of ______________ since it changes a-c to pulsating d-c.

1·7 (rectification *or* detection, etc.) A simple crystal set circuit is shown (Fig. 1·7). The required resonant assembly is formed by the combination of *L* and ______.

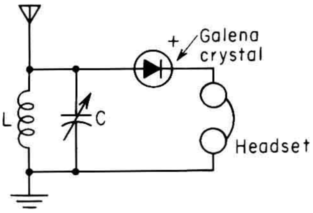

Fig. 1·7

1·8 (*C*) The station to be heard is selected by adjusting the variable capacitor *C*. Detection or rectification is then accomplished by use of the ____________ crystal, and reproduction of the audio is handled by the headset.

1·9 (galena) A semiconductor crystal rectifier is universally symbolized as shown (Fig. 1·9). The triangular element bears no identifying marks, but the "flat-plate" element here is identified by a ____________ sign; such a sign is not always included.

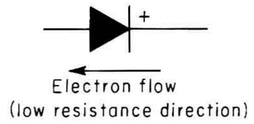

Fig. 1·9

1·10 ("+") The symbol is always used as shown to indicate the direction of conductivity for electrons. Electrons flow easily in the direction of the arrow. Thus, electrons flow easily from the flat-plate element toward the ____________ element.

1·11 (triangular) The reason for the "+" designation used on the flat-plate element can be seen from Fig. 1·11. In this circuit, a(n) ______ generator is shown in a circuit containing a crystal rectifier and a load.

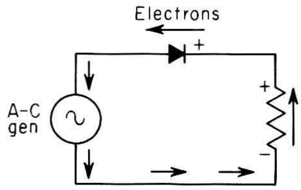

Fig. 1·11

1·12 (a-c) The direction of ____________ flow is shown by the arrows; we might call this the direction of electron conductivity.

1·13 (electron) It is seen that the flat-plate element is at the same potential as the *positive* end of the load resistor. Hence, the flat plate is labeled ______.

1·14 ("+") During World War II, efficient semiconductor rectifiers were widely used (Fig. 1·14). By this time, galena had been abandoned as a semiconductor and was replaced by a better material. As shown in Fig. 1·14, this new semiconductor material is called ____________.

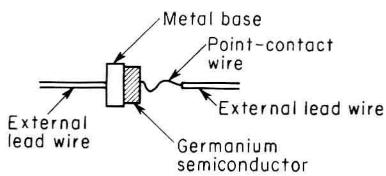

Fig. 1·14
