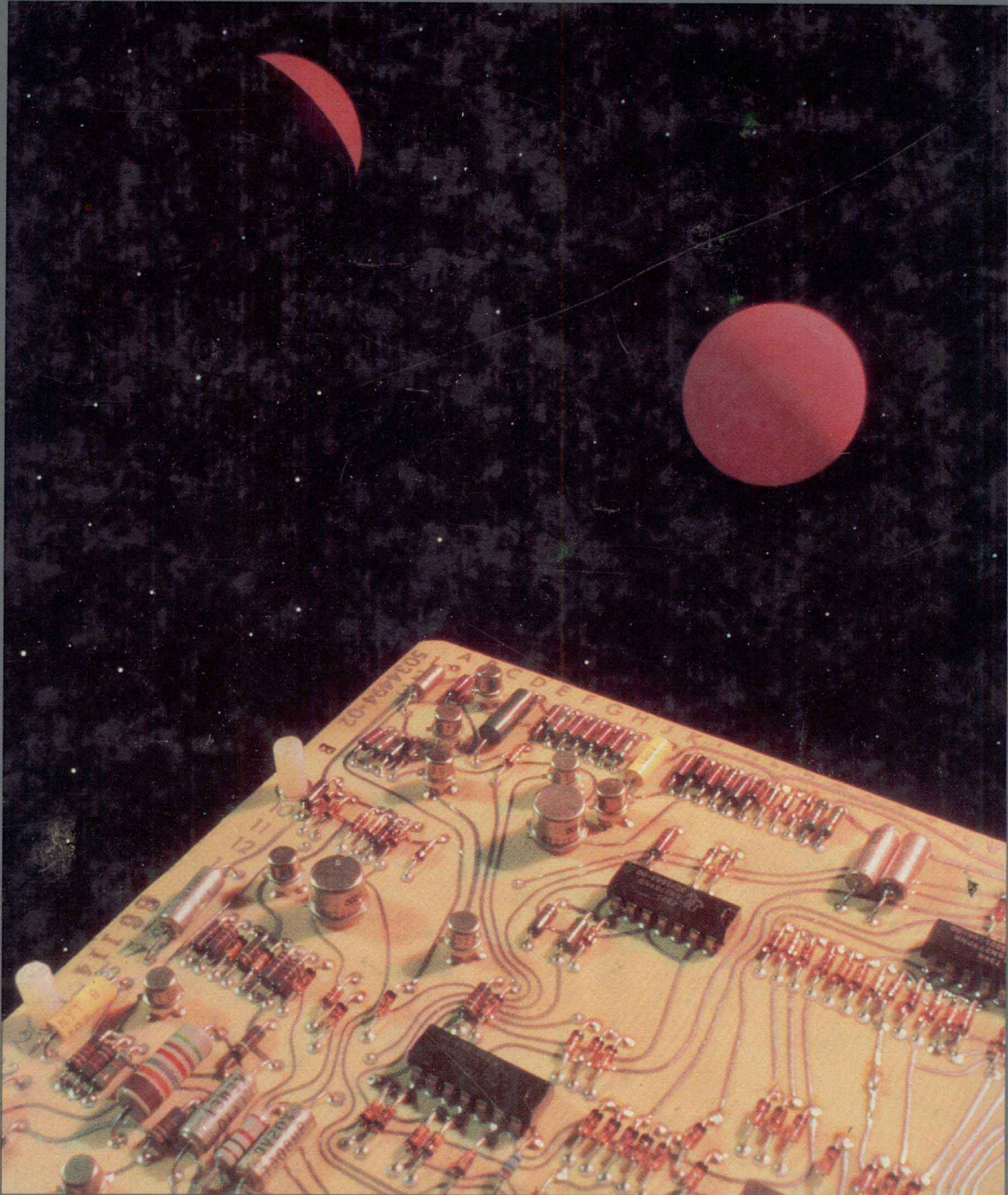


ELECTRIC CIRCUITS FUNDAMENTALS



F L O Y D

Thomas L. Floyd

**ELECTRIC
CIRCUITS
FUNDAMENTALS**

**Merrill Publishing Company
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To Sheila, once again, for her love and support

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Preface

Electric Circuits Fundamentals covers the essential topics in dc and ac circuits with emphasis on applications and troubleshooting. The coverage provides a thorough foundation on which to develop skills in electronics and related fields.

This book is designed particularly for those students in technician-level programs in technical institutes, community colleges, and vocational/technical schools. Emphasis is on the understanding and application of basic concepts. Mathematics is held to a minimum and is used only in a supportive role where it is essential for the development of a complete and meaningful coverage of a topic or for providing a means of analyzing basic circuit operation.

Some of the specific features are:

- Chapter objectives
- Application assignments
- Application notes
- Calculator sequences
- Section reviews with answers at the end of the chapter
- Two-color format throughout; use of color in the art program is *functional*, emphasizing concepts
- Full-color section keyed to figures, problems, section reviews, and examples
- Many photographs
- Over 880 illustrations
- Over 200 numbered examples
- Emphasis on applications and troubleshooting
- End-of-chapter summaries
- Self-tests at the end of each chapter with solutions at the end of the book
- Two end-of-chapter problem sets (one easier, the other more difficult); answers to odd-numbered problems at the end of the book
- Glossary at the end of the book
- Availability of a coordinated lab manual and a set of transparencies

Chapter Organization

At the beginning of each chapter, the introduction provides an overview of the material to be covered, and the *objectives* list itemizes the specific things that the student will learn.

The *Application Assignment* at the beginning of each chapter places the students in a practical on-the-job situation as technicians and requires them to complete the assignment based on knowledge gained during the study of the chapter. These Application Assignments are intended to be not only educational, but also motivational. They put the students in a situation to which they can relate but which they are generally unable to handle before studying the chapter. After completing the material in the chapter, however, they can successfully carry out the assignment and thus derive a sense of accomplishment. The *Application Note* at the end of the chapter provides a suggested approach or solution to the assignment.

Calculator Sequences are provided for selected examples to show the student how to use a typical calculator (TI55-II; sequence may vary for other calculators) to arrive at the solution. Generally, these appear where an unfamiliar mathematical procedure is first introduced.

The *Section Reviews* consist of questions and problems which focus on key concepts presented in that section in order to provide students with frequent feedback on their comprehension of the material. Answers are given at the end of the chapter.

The *Summary* at the end of the chapter provides a concise listing of facts, definitions, new symbols, and a formula list.

The *Self-test* at the end of the chapter allows the students to check their mastery of the general concepts covered in the chapter. The self-test consists of essay-type questions, definitions, and multiple-choice questions as well as basic problems requiring some calculation. Solutions to all self-tests appear at the end of the book.

There are two problem sets at the end of each chapter. Problem Set A is a sectionalized series of relatively straightforward exercises, and Problem Set B contains exercises that are more demanding and thought provoking. Answers to the odd-numbered problems appear at the end of the book.

In the first six chapters, a number of figures, problems, section reviews, and examples relate to a unique full-color section (positioned between pages 128 and 129). In these exercises, the students are required to identify simple component relationships in actual breadboard assemblies or on printed circuit boards, to determine resistance values directly from the color bands, and to read instruments connected to operating circuits in order to analyze or troubleshoot the circuit.

Overall Organization of the Text

The text is divided into two parts: DC Circuits, consisting of Chapters 1 through 8; and AC Circuits, consisting of Chapters 9 through 16.

For those wishing to introduce capacitance and inductance in the dc portion of the course, all of Chapter 10 except Sections 10–6 and 10–7 and all of Chapter 11 except Sections 11–6 and 11–7 can be added to the dc coverage.

Then, Sections 10–6, 10–7, 11–6, and 11–7 can be covered as part of the ac course.

The organization and content of this book are suited to those programs which cover dc and ac in either a one-term or a two-term sequence.

Acknowledgments

This book is the result of the efforts of many people. In particular, I want to express my appreciation to Don Thompson, Connie Geldis, Tim McEwen, Cindy Brunk, Bruce Johnson, Jim Hubbard, Terry Tietz, and Cathy Watterson at Merrill Publishing Company for their work in making this book a reality. As always, the people at Merrill are progressive, creative, and dedicated to quality. My thanks also go to the following instructors who reviewed the manuscript and provided many valuable suggestions: Roman R. Braun, Terrence D. Nelson, and Kenneth J. Dreistadt, Lincoln Technical Institute; Robert A. Ciuffetti, Sylvania Technical Institute; John Colyer, ITT Technical Institute—Austin; Kenneth Edwards, International Brotherhood of Electrical Workers; William Greer, Albuquerque Technical Vocational Institute; Jill Harlamert, DeVry Institute of Technology—Columbus; Steve Kalina, DeVry, Inc.; Arnold Kroeger, Hillsborough Community College; Floyd Martin, Santa Ana College; W. A. McIntyre, DeVry Institute of Technology—Chicago; and Tim Staley, DeVry Institute of Technology—Dallas. In addition, I thank Morris McCarthy, DeVry—Atlanta, for suggesting the four-color insert and Dean Gay Farmer, DeVry—Columbus, for his help in implementing this suggestion. Art Vildavs, Joyce Mielke, and Sam McCord, all students at DeVry Institute of Technology—Columbus, helped to build and to set up the circuits for the full-color photographs. I am grateful to the following industrial organizations that contributed photographs and other technical material for use in this book: Tektronix, Texas Instruments, Grumman Corporation, Burroughs Corporation, Motorola Semiconductor Products, E. I. duPont de Nemours and Company, Hewlett-Packard, Bell Laboratories, B&K Precision/Dynascan Corporation, Triplett, Bussman, Eaton, Grayhill, Bourns Trimpot, Dale Electronics, Radio Shack, Ford, Murata Erie, Delevan, and Sprague Electric. Finally, my wife, Sheila, deserves a great deal of credit for her help and support during the development of this book.

Thomas L. Floyd

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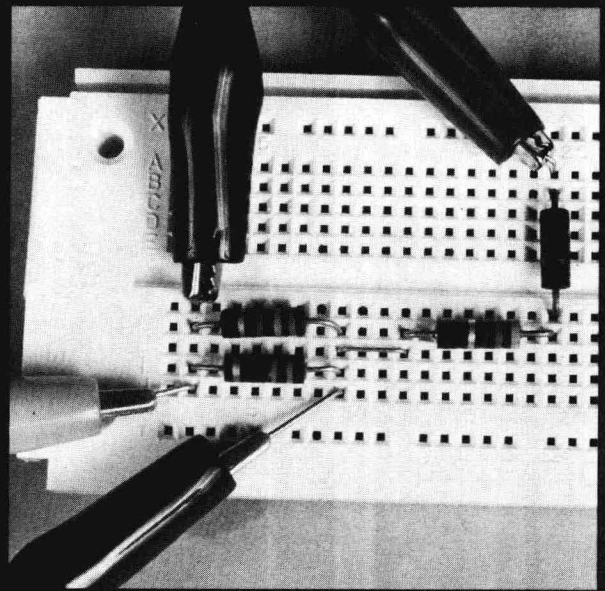
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COLOR INSERT: Actual Circuits for Examples, Section Reviews, and Problems

This special 16-page full-color insert illustrates actual color-coded resistors and real-world circuits that are used in examples, section reviews, and end-of-chapter problems, thereby taking the student "into the lab" and placing him or her "on the job."

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- 2 THE BASIC ELECTRICAL QUANTITIES
- 3 OHM'S LAW AND POWER
- 4 SERIES CIRCUITS
- 5 PARALLEL CIRCUITS
- 6 SERIES-PARALLEL CIRCUITS
- 7 MAGNETISM AND ELECTROMAGNETISM
- 8 MEASURING INSTRUMENTS

PART ONE DC CIRCUITS



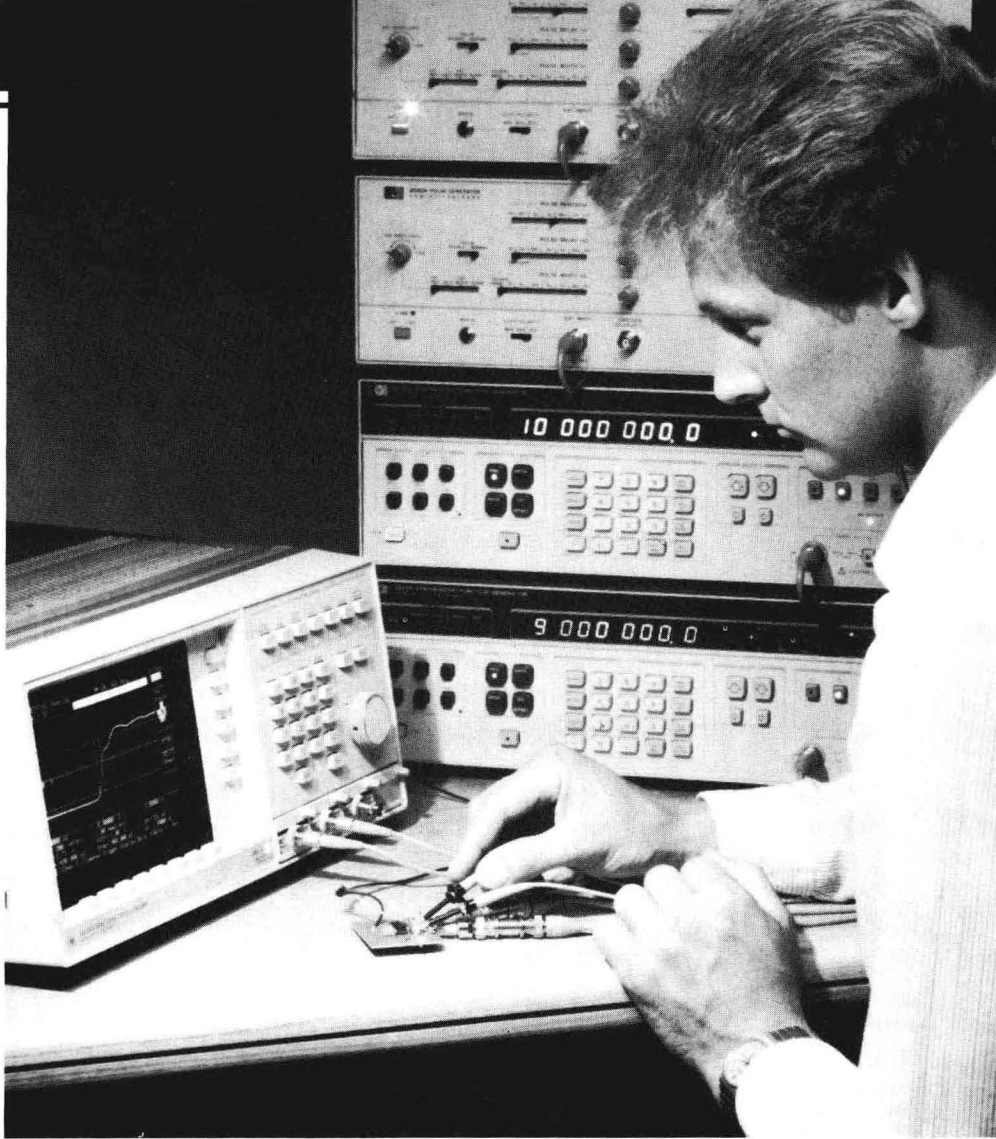
Introduction

- 1-1 History of Electricity and Electronics
- 1-2 Careers in Electronics
- 1-3 Applications of Electricity and Electronics
- 1-4 Circuit Components and Measuring Instruments
- 1-5 Electrical Units
- 1-6 Scientific Notation
- 1-7 Metric Prefixes

This chapter presents a brief history of the fields of electricity and electronics and discusses some of the many areas of application. Also, to aid you throughout the book, the basics of scientific notation and metric prefixes are reviewed, and the quantities and units commonly used in electronics are introduced.

In this chapter you will learn:

- A brief history of electricity and electronics.
- Some of the important areas in which electronics technology is applied.
- How to recognize some important electrical components and measuring instruments.
- The electrical quantities and their units.
- How to use scientific notation (powers of ten).
- The metric prefixes and how to use them.



APPLICATION ASSIGNMENT

At the beginning of each chapter starting with Chapter 2, you will find an Application Assignment that relates to that chapter. These assignments present a variety of practical job situations that a technician might encounter in industry.

As you study each chapter, think about how to approach the Application Assignment. When you have completed each chapter, you should have a sufficient knowledge of the topics covered to enable you to carry out the assignment. An Application Note at the end of the chapter suggests an approach or offers a solution to the assignment.

HISTORY OF ELECTRICITY AND ELECTRONICS

1-1

One of the first important discoveries about static electricity is attributed to William Gilbert (1540–1603). Gilbert was an English physician who, in a book published in 1600, described how amber differs from magnetic loadstones in its attraction of certain materials. He found that when amber was rubbed with a cloth, it attracted only lightweight objects, whereas loadstones attracted only iron. Gilbert also discovered that other substances, such as sulfur, glass, and resin, behave as amber does. He used the Latin word *elektron* for amber and originated the word *electrica* for the other substances that acted similarly to amber. The word *electricity* was used for the first time by Sir Thomas Browne (1605–82), an English physician.

Another Englishman, Stephen Gray (1696–1736), discovered that some substances conduct electricity and some do not. Following Gray's lead, a Frenchman named Charles du Fay experimented with the conduction of electricity. These experiments led him to believe that there were two kinds of electricity. He called one type *vitreous electricity* and the other type *resinous electricity*. He found that objects charged with vitreous electricity repelled each other and those charged with resinous electricity attracted each other. It is known today that two types of electrical *charge* do exist. They are called *positive* and *negative*.

Benjamin Franklin (1706–90) conducted studies in electricity in the mid-1700s. He theorized that electricity consisted of a single *fluid*, and he was the first to use the terms *positive* and *negative*. In his famous kite experiment, Franklin showed that lightning is electricity.

Charles Augustin de Coulomb (1736–1806), a French physicist, in 1785 proposed the laws that govern the attraction and repulsion between electrically charged bodies. Today, the unit of electrical charge is called the *coulomb*.

Luigi Galvani (1737–98) experimented with current electricity in 1786. Galvani was a professor of anatomy at the University of Bologna in Italy. Electrical current was once known as *galvanism* in his honor.

In 1800, Alessandro Volta (1745–1827), an Italian professor of physics, discovered that the chemical action between moisture and two different metals produced electricity. Volta constructed the first battery, using copper and zinc plates separated by paper that had been moistened with a salt solution. This battery, called the *voltaic pile*, was the first source of steady electric current. Today, the unit of electrical potential energy is called the *volt* in honor of Volta.

A Danish scientist, Hans Christian Oersted (1777–1851), is credited with the discovery of electromagnetism, in 1820. He found that electrical current flowing through a wire caused the needle of a compass to move. This finding showed that a magnetic field exists around a current-carrying conductor and that the field is produced by the current.

The modern unit of electrical current is the *ampere* (also called *amp*) in honor of the French physicist André Ampère (1775–1836). In 1820, Ampère measured the magnetic effect of an electrical current. He found that two wires carrying current can attract and repel each other, just as magnets can. By 1822, Ampère had developed the fundamental laws that are basic to the study of electricity.

One of the most well known and widely used laws in electrical circuits today is *Ohm's law*. It was formulated by Georg Simon Ohm (1789–1854), a

German teacher, in 1826. Ohm's law gives us the relationship among the three important electrical quantities of resistance, voltage, and current.

Although it was Oersted who discovered electromagnetism, it was Michael Faraday (1791–1867) who carried the study further. Faraday was an English physicist who believed that if electricity could produce magnetic effects, then magnetism could produce electricity. In 1831 he found that a moving magnet caused an electric current in a coil of wire placed within the field of the magnet. This effect, known today as *electromagnetic induction*, is the basic principle of electric generators and transformers.

Joseph Henry (1797–1878), an American physicist, independently discovered the same principle in 1831, and it is in his honor that the unit of inductance is called the *henry*. The unit of capacitance, the *farad*, is named in honor of Michael Faraday.

In the 1860s, James Clerk Maxwell (1831–79), a Scottish physicist, produced a set of mathematical equations that expressed the laws governing electricity and magnetism. These formulas are known as *Maxwell's equations*. Maxwell also predicted that electromagnetic waves (radio waves) that travel at the speed of light in space could be produced.

It was left to Heinrich Rudolph Hertz (1857–94), a German physicist, to actually produce these waves that Maxwell predicted. Hertz performed this work in the late 1880s. Today, the unit of frequency is called the *hertz*.

The Beginning of Electronics

The early experiments in electronics involved electric currents flowing in glass tubes. One of the first to conduct such experiments was a German named Heinrich Geissler (1814–79). Geissler found that when he removed most of the air from a glass tube, the tube glowed when an electrical potential was placed across it.

Around 1878, Sir William Crookes (1832–1919), a British scientist, experimented with tubes similar to those of Geissler. In his experiments, Crooke found that the current flowing in the tubes seemed to consist of particles.

Thomas Edison (1847–1931), experimenting with the carbon-filament light bulb that he had invented, made another important finding. He inserted a small metal plate in the bulb. When the plate was positively charged, a current flowed from the filament to the plate. This device was the first *thermionic diode*. Edison patented it but never used it.

The electron was discovered in the 1890s. The French physicist Jean Baptiste Perrin (1870–1942) demonstrated that the current in a vacuum tube consists of negatively charged particles. Some of the properties of these particles were measured by Sir Joseph Thomson (1856–1940), a British physicist, in experiments he performed between 1895 and 1897. These negatively charged particles later became known as *electrons*. The charge on the electron was accurately measured by an American physicist, Robert A. Millikan (1868–1953), in 1909. As a result of these discoveries, electrons could be controlled, and the electronic age was ushered in.

Putting the Electron to Work

A vacuum tube that allowed electrical current to flow in only one direction was constructed in 1904 by John A. Fleming, a British scientist. The tube was used