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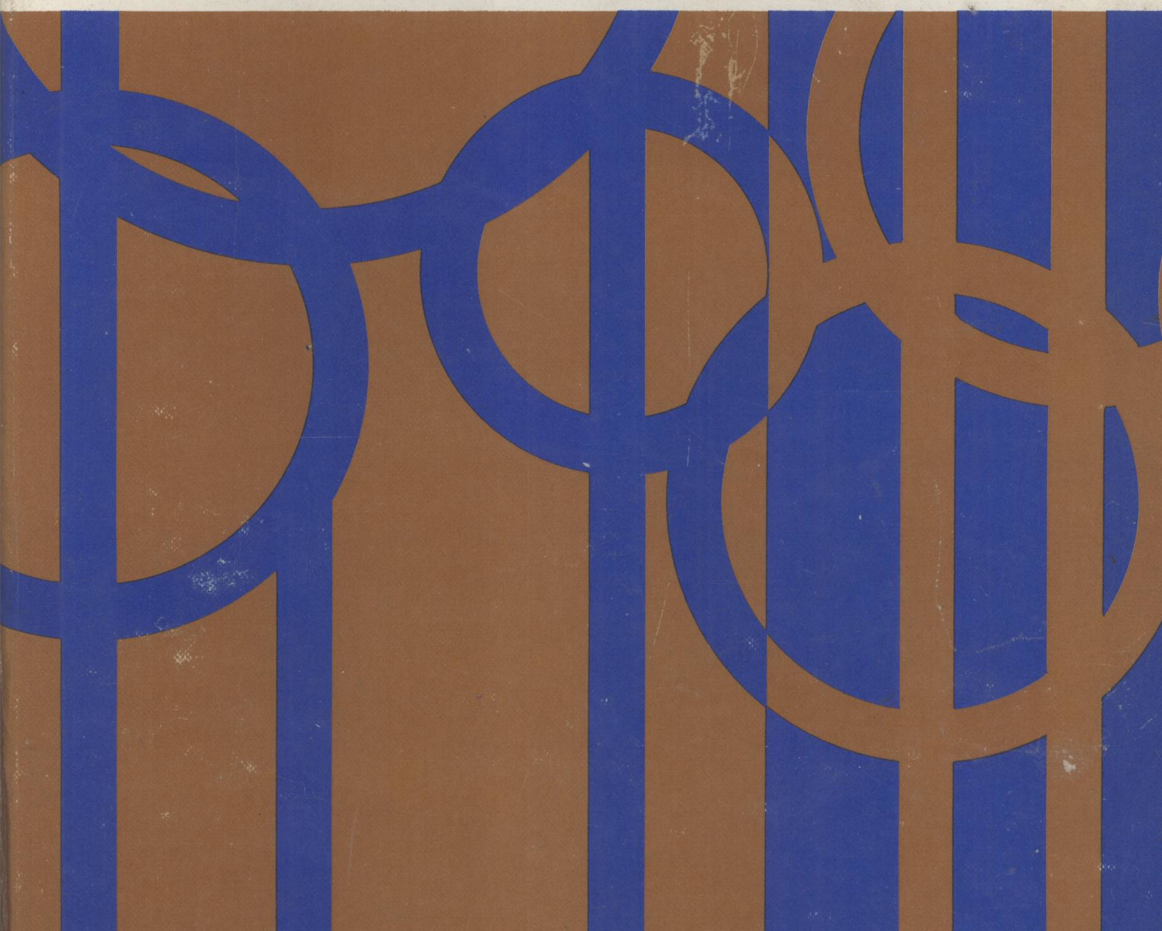

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PREFACE

Fundamental Circuit Analysis is a modern approach to electrical theory for electronics. As the technology of the electronic industry continues to advance, topics that were formerly relevant are now obsolete. This text has replaced those topics with theory more compatible with industry's requirements for today's electronics graduates. The study of the D'Arsonval movement, for example, is no longer so important, because of the technical advancement of digital multimeters. Symmetrical filters and integrated circuits are better analyzed with Bartlett's network theorem—a theorem that has seldom appeared in other technician level textbooks. Practical applications are frequently illustrated to motivate student learning.

A unique approach taken throughout this text is to integrate programming methods for routine problem solving. This philosophy is in keeping with the current trend of both industry and institutions of higher learning to provide access to "computer power" via on-line terminals. Sophisticated nonprogrammable electronic pocket calculators have been on the market for years. The sight of students with the newer electronic programmable calculators is now becoming increasingly commonplace, especially as the costs of these devices constantly decrease.

Inherent in these technical advances will be the necessity for technicians, whether using computer terminals or programmable pocket calculators, to have mastered at least basic programming techniques if they are to take advantage of the benefits offered by these "tools." It is inevitable, therefore, that new textbooks will find it increasingly necessary to integrate programming concepts with basic circuit theory. Such a combination permits the optimization of the man-computer interface—the computer and/or calculator doing what it does best: routine high speed calculations; man doing what he does best: logical, deductive thinking. This textbook is a pioneer toward that approach.

Accepting that a combination of electronic hardware theory and programming ability is "the way to go," a natural question then arises: What programming language should be utilized? Many formal programming languages are available, such as APL, FORTRAN, BASIC, etc. In addition, practically every programmable calculator has a set of rules and an instruction repertoire oriented uniquely to itself. The choice should be made so that the electronic theory is not so subjugated as to result in a software oriented textbook. Most importantly, there is an inherent transference of concepts and methodologies regardless of the language utilized. The choice, then, should be a language that is easy to comprehend (conversational in nature); oriented toward projected future trends; and one which is more universally accessible for study as opposed to being structured for a special purpose. BASIC was chosen because it is both English-language oriented in its command statements and is also in keeping with current industrial trends such as timesharing (many isolated programmers, each simultaneously using remote terminals to share powerful computing systems). Additionally, some languages such as FORTRAN have the added complication of requiring an associated "format" statement with each output command; a problem not encountered using BASIC.

Sophisticated "string" techniques, which are better employed by professional programmers for report generation, are omitted. Only those elementary statements oriented toward mathematical solutions are discussed. Reasonably advanced programming can be mastered in a minimum amount of time, thereby continuing to give major emphasis to the basic electrical theory. At no time have the authors attempted to emphasize programming at the expense of circuit theory, but rather to integrate into the theory the use of the computer as a modern tool of circuit interpretation. No prerequisite knowledge is necessary for this phase of the text.

The mathematical rigor of the text has been designed to coincide with a standard course in algebra and trigonometry. Although the first chapter uses scientific notation, these concepts are explained thoroughly. Subsequent chapters progress from simple linear equations to quadratic functions and "j" operators. The occasional use of the delta function (average change) illustrates laws and does not require an understanding of the calculus.

Alternating current theory is presented with an emphasis on the methods of solving circuits. Rather than trying to present all the possible variations of series and parallel combinations, the authors have chosen to develop an *approach* to the solution which will apply to any ac circuit. Network theorems are generously used in developing complex ac network analysis.

The sections on magnetism and electrostatics go beyond presentations found in traditional texts. Such topics as magnetic bubble theory and charge coupling find particular application in the storage of digital information. For this reason the authors have chosen to develop a groundwork of understanding in these areas.

Alternating current filters are introduced as a survey of the types and classifications. Exploration of detailed theory goes far beyond the capacity of a book on fundamental circuits. Here again, the student is offered an approach rather than a compendium.

The basic objective of this book is the effective preparation of the student for a changing industry environment, that is increasingly oriented toward computer and digital electronics.

CONTENTS

PART I

Many questions arise when a student begins the study of electronics. Some of these questions are personal in nature; others are technical. In the former group, a student may say to himself: "I am going to spend several years of study for a degree in electronics. Is there a future?" To answer this question, consider the vast spectrum of current electronic applications. In that area of specialization referred to as *discrete* or *digital electronics*, applications in the computer field alone can range from sophisticated pocket calculators (of the type currently used by many students) to computerized photoenhancement of distant planetary pictures telemetered back to Earth. In that area of specialization referred to as *analog* or *communication type electronics*, many new commercial areas are developing. One such area of far-reaching significance includes the electronic circuits used in conjunction with fiber optics, a new media replacing coaxial cable and copper wiring for the transmission of telephone and TV signals. There is not room enough here to state all of the many exciting new areas in which electronics finds application. To answer the question previously posed, there is indeed a future in electronics.

The second area in which many students initially seek answers is technical in nature. What constitutes electronics? Is it difficult? At what level should I start? All of these questions are typical for the new entrant. Their answers now bring us to PART I of this textbook. In fact, these questions may best be answered in reverse order.

Where do I start? Obviously, with a good foundation. PART I starts with the fundamental concepts and laws governing scientific notation which, incidentally, is universally applicable throughout all scientific disciplines. It continues by discussing such fundamental ideas as:

1. When you speak of a 12-volt car battery, what is meant by a "volt"?
2. When the tag on the back of a TV set says "rated at 3.5 amps," what exactly is meant by an amp?
3. What is resistance?

These and other similar concepts form the foundation upon which the more complex principles are built.

Is it difficult? Not by applying good study habits right from the beginning. Read the material carefully and study the examples. Use the answers to problems supplied at the end of the textbook as a check against your work, not as a quick "cop-out" to handing in last night's assignment.

What constitutes electronics? This concept and the laws governing measurable electronic quantities are covered in the sequential chapters. The important first step is to build that foundation upon which comprehensions must lie. PART I of this text constitutes that foundation. Welcome to your future.

CHAPTER 1

NOTATIONS, SYSTEMS, AND CONVERSIONS

1.1 SCIENTIFIC NOTATION

The most common usage of mathematics, that of manipulating numbers, is an everyday occurrence. It may consist of averaging student test scores, balancing one's checking account, paying for and receiving change from purchases, etc. The normal magnitude of these everyday encountered numbers is usually within an easily recognizable range. In many occupations, however, one can encounter numbers in magnitudes not so easily recognizable. For example, persons working with federal or other governmental budgets will work in number magnitudes usually beyond the average everyday range. An even more illustrative example involves persons working in sciences such as astronomy. A typical number might look like

5,874,000,000,000 miles

This is the approximate distance in miles that light travels in one year, a frequent measurement of length in the science of astronomy. The field of electronics also has examples of large numbers. Frequency, measured in units called *hertz* (Hz), might look like

160,250,000 Hz

In order to simplify the reading (or writing) of numbers of unusual magnitudes, a system of number notations has been developed. It is called *scientific notation.* As is to be expected, expression in scientific notation involves the application of simple rules to reduce the number in question to a more recognizable magnitude. For numbers greater than 1, the rule is as follows: *Move the decimal point to the left until the value of the number is between 1 and 10. Multiply this resultant by 10 raised to a positive power equal to the number of places the decimal point was shifted leftward.*

If the decimal point in the above example of one light year's distance is moved to the left until the value represents a number between 1 and 10, then it can be seen that the decimal point must be shifted 12 places. To retain the original value of the number, we must now multiply the resultant 5.874 times 10 raised to a power equaling the number of places the decimal point was shifted. Since the decimal point has been moved 12 positions to the left, the correct notation of this example is 5.874×10^{12}. By the same analogy, if the frequency example were written in scientific notation, its value could be expressed as 1.6025×10^{8}.

Example 1.1 Rewrite each of the following numbers in scientific notation:

a. $3,256 = 3.256 \times 10^3$
b. $1,750,000 = 1.75 \times 10^6$
c. $2,115,000,000 = 2.115 \times 10^9$
d. $42.7 = 4.27 \times 10^1$

Numbers can also frequently occur in extremely minute quantities. For example, the definition of *capacitance* (an electronic term to be studied in subsequent chapters) is measured in a unit called the *farad*. As the reader will learn, a farad is a rather large unit of measurement. If defined in this unit, a typical capacitor value might look like

0.00000000015 farad

Another example would be to write the charge of an electron in terms of the unit definition of charge, namely, the *coulomb*. The electron charge would be written as follows

0.00000000000000000016 coulomb

As can be seen, very small numbers written in this manner also present some difficulty in grasping their value. To write a number whose value is less than 1 in scientific notation, the rule is as follows: *Move the decimal point to the right until the value of the number is between 1 and 10. Multiply the resultant by 10 raised to a negative power equal to the number of places the decimal point was shifted rightward.*

If the decimal point in the above value of capacitance is to be moved to the right until the value represents a number between 1 and 10, then it can be seen that the decimal point must be shifted 10 places. To retain the original value of the number, we must now multiply the resultant 1.5 times 10 raised to a power equaling the number of places the decimal point was shifted. Since the decimal point has been moved 10 positions to the right, the correct notation of the above example is 1.5×10^{-10}. By the same analogy, if the charge on the electron were written in scientific notation, its value would be expressed as 1.6×10^{-19}.

Example 1.2 Rewrite each of the following numbers in scientific notation:

a. $0.00126 = 1.26 \times 10^{-3}$
b. $0.169 = 1.69 \times 10^{-1}$
c. $0.0000025 = 2.5 \times 10^{-6}$
d. $0.000200 = 2 \times 10^{-4}$

As another application illustrating how much easier it is to read scientific notation, suppose it is desired to recognize which of the following two numbers is the larger:

0.00000000000123

or

0.000000000000567

On the surface it appears that the significant digits of the second number, namely 567, would be larger than the significant digits of the former number, namely 123. However, when expressed in scientific notation, the two numbers appear as 1.23×10^{-12} and 5.67×10^{-13}. The powers of 10 of the second number indicated that the decimal point is actually further to the left of the first significant digit than is the case with the former number, and hence the second number is actually the smaller of the two.

As a further aid in making it easier to express numbers, a prefix is frequently used in conjunction with the unit designation. Just as commas are used after every third zero in very large numbers, so it is that each prefix is representative of powers of 10 measured in units of 3. Refer to Table 1.1. Notice that in starting with the smallest prefix (pico) and progressing upward toward the largest (tera), each successive prefix is one thousand times larger than its predecessor. Since 1000 represents three zeros, it follows that all exponents of 10 assigned a prefix name are divisible by 3. This rule applies when the power is greater than $|3|$. Ten raised to the power ± 1 is called *deca* and *deci* respectively, and 10 raised to the power ± 2 is called *hecto* and *centi* respectively. For example, 10^{-5} and 10^{8} do not have assigned prefix names. Also take note that 10^{0} equals unity. For that matter, any coefficient except zero, when raised to the power of 0, has a value of unity. If we are to utilize these abbreviations, a slight modification will have to be made to the methodology of

TABLE 1.1

Number	Power of 10	Prefix	Abbreviation
1,000,000,000,000	10^{12}	tera	T
1,000,000,000	10^{9}	giga	G
1,000,000	10^{6}	mega	M
1,000	10^{3}	kilo	k or K
1	10^{0}	—	—
0.001	10^{-3}	milli	m
0.000001	10^{-6}	micro	μ
0.000000001	10^{-9}	nano	n
0.000000000001	10^{-12}	pico	p