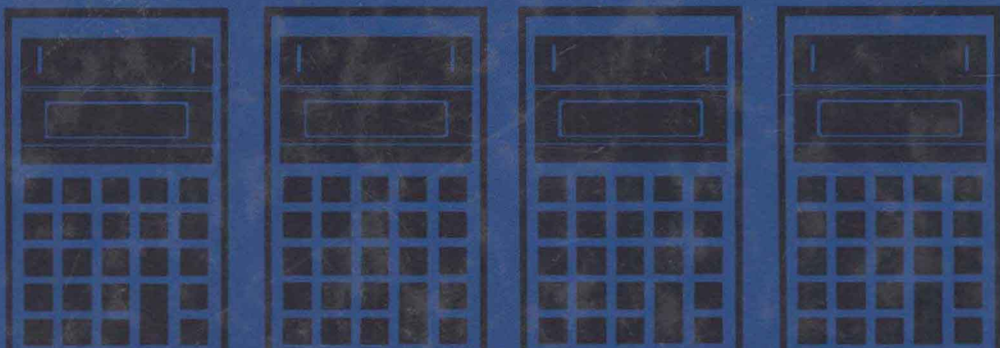
MATH FOR ELECTRONICS

A Modern Approach



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MATH FOR ELECTRONICS

PREFACE

Math for Electronics: A Modern Approach is designed for use in vocational-technical and industry-sponsored schools, and for introductory college and university electronics technology programs. It will also serve as a useful reference for electronics technicians who need an efficient mathematical guide for solving electronics problems.

This introductory text uses an ''applications-oriented'' approach for teaching math for electronics. Students are introduced to the fundamental concepts of electronics together with the mathematical techniques necessary for describing the behavior of electronic circuits. As with most technical learning, the application (electronics, in this case) dictates the need for a tool (math, in this case). As we use the tool, the theory and applications become more easy to understand. In this book the electronic applications give purpose and reality to the math. In turn, the math helps to explain how electronic circuits function. This approach simplifies the problem of expecting the student to bridge the gap between mathematical theory and electronic circuit design. Each chapter of this text is organized to include learning *objectives,* an easy-to-understand *discussion* of a major topic, a chapter *summary,* and end-of-chapter *problems.*

Tomorrow's technology demands that today's students acquire a degree of computer literacy that enhances efficient understanding and design of electronic systems. It is equally important that today's students be proficient in the use of scientific electronic calculators. Many calculator procedures and prompted computer programs for solving electronic problems are included in this text. The calculator procedures encourage students to feel comfortable with the capabilities of the scientific calculator while learning to solve problems efficiently. The computer programs have the multiple objectives of familiarizing students with the usefulness of microcomputers and applications software, encouraging more problem solving, and reinforcing the idea that once the structure of a problem is known, the mathematical solution is only a matter of fitting the correct values into the solution structure.

The principal learning objective inherent in this text is that the student may attain a joint understanding of basic electronics and applied mathematics which forms the foundation for a strong program in electronics technology. The text is organized to proceed from elementary math needed for beginning concepts in electronics, to the more specialized applications of mathematics, to the range of electronics problems found in most introductory electronics courses. The first group of chapters deals with whole numbers, fractions, decimals, arithmetic, and algebra used in direct-current (dc) circuits, voltage dividers, and measurement circuits. The next group of chapters advances to vectors and trigonometry, complex numbers, and graphs helpful in understanding alternating-current (ac) theory and applications. The last group concludes with the more specialized applications of frequency-sensitive circuits, decibels, power supplies, solid-state and digital logic with associated treatment of logarithms, analytic geometry, and those techniques in calculus which have to do with rate of change. A comprehensive electronic glossary is included (Appendix A) to provide easy access to electronic terminology as the need arises.

The approach used in this text is to introduce mathematical concepts prior to electronic concepts. In most cases, a chapter dealing with mathematical operations is followed immediately with a chapter that provides applications for electronic circuits. The use of calculators and the use of computer programs are stressed as problem-solving methods.

Also included with this book is a "Problem-Solving Supplement" which provides additional problems for each chapter and answers for the problems at the ends of chapters.

In addition, a diskette with the computer programs used in this book is available from Prentice Hall. It is intended for use with the IBM-PC or compatibles, but may easily be modified for use with other systems.

The authors are indebted to Kevin Smathers of Vanderbilt University and Neal Jett of the University of Kentucky for their help in developing the IBM/PC-compatible programs. In addition, the authors wish to thank Becky Sparks of Eastern Kentucky University for typing this manuscript and Robert Browning, lab technician at E.K.U., for testing the computer programs used in this text.

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1

INTRODUCTION

Any area of study must rely on certain basic information. To gain a thorough understanding of electronics one must have a good knowledge of basic mathematical operations. Almost all areas of electronics technology require a strong background in basic mathematical theory.

OBJECTIVES

Upon completion of this chapter, you will be able to:

- gain an understanding of the terminology used in the field of electronics technology
- recognize common symbols used for electronic circuits
- use mathematical and electronic symbols for problem solving
- discuss the SI system of units and the metric system of measurement
- apply proper procedures for unit conversion and scientific notation
- apply calculator and computer procedures to solve unit conversion, scientific notation, and metric conversion problems

ELECTRONICS TERMINOLOGY AND SYMBOLS

There are several terms listed in Appendix A, Comprehensive Electronics Glossary, which are used in the field of electronics technology. An understanding of symbols is also important for all types of electronic technicians and engineers. Technicians and engineers must be able to design, troubleshoot, modify, and improve electronic circuits. These skills require a knowledge of terminology, symbols, and mathematical operations. The terms listed in Appendix A provide a simplified review of terms that are commonly used in electronics technology. It may also be necessary at this time to preview electronic symbols (see Appendix B) while studying mathematical applications for electronics. These provide a foundation for further study of electronic circuits.

MEASUREMENT FUNDAMENTALS

Electronic quantities are values that are calculated or measured. Electronic circuits depend on accurate measurements for tests and analysis. Thus many types of measurements and measuring equipment are associated with electronic circuits.

Today, most nations of the world use the metric system of measurement. In the United States, the National Bureau of Standards began a study in 1968 to determine the feasibility and costs of converting the nation to the metric measurement system. Today, this conversion is still taking place.

The units of the metric system are decimal measures based on the kilogram and the meter. Although the metric system is very simple, several countries have been slow to adopt it. The United States has been one of these reluctant countries, due to the complexity of actions required by a complete changeover of measurement systems.

MEASUREMENT QUANTITIES

Most measurement is based on the International System of Units (SI). The basic units of this system are the meter, kilogram, second, and ampere (MKSA). These are the units of length, mass, time, and electrical current. Other systems, such as the meter–kilogram–second (MKS) and the centimeter–gram–second (CGS), recognize only three base units. However, these two systems are closely associated with the metric system.

Measurement Quantity	SI Unit
Area	square meter
Volume	cubic meter
Frequency	hertz
Density	kilogram per cubic meter
Velocity	meter per second
Acceleration	meter per second per second
Force	newton
Pressure	pascal (newton per square meter)
Work (energy), quantity of heat	joule
Power (mechanical, electrical)	watt
Electrical charge	coulomb
Permeability	henry per meter
Permittivity	farad per meter
Voltage, potential difference, electromotive force	volt
Electric flux density, displacement	coulomb per square meter
Electric field strength	volt per meter
Resistance	ohm
Capacitance	farad
Inductance	henry
Magnetic flux	weber
Magnetic flux density (magnetic induction)	tesla
Magnetic field strength (magnetic intensity)	ampere per meter
Magnetomotive force	ampere
Magnetic permeability	henry per meter
Luminous flux	lumen
Luminance	candela per square meter
Illumination	lux

Figure 1-1 International system of derived units.

There are several derived units that are used extensively for electrical and other related measurements. Most of the units used for electronic circuit measurements are part of the International System of Units (SI) and are based on the meter–kilogram–second–ampere (MKSA) system. The International System of Derived Units is shown in Figure 1-1.

CONVERSION OF ELECTRICAL UNITS

Sometimes it is necessary to make conversions of electrical units so that very large or very small numbers may be avoided. For this reason, decimal multiples and submultiples of the basic units have been developed by using standard prefixes. These standard prefixes are shown in Figure 1-2. As an example, we may express 1000 volts (V) as 1 kilovolt (kV) or 0.001 ampere (A) as 1 milliampere (mA). A chart that shows the relationship of these prefixes appears in Figure 1-3.

Small-Unit Conversion

The electrical unit used to measure a specific quantity is often less than 1. Examples of this are 0.2 volt, 0.875 ampere, and 0.85 watt. When this occurs, *prefixes* are used. Some prefixes for units less than 1 are shown in the lower portion of Figure 1-2. Notice that a millivolt is 1/1000 of a volt and a microampere is 1/1,000,000 of an ampere. These prefixes may be used with any electrical unit of measurement. The unit is divided by the fractional part of the unit. For example, if 0.0008 A is changed to microamperes, 0.0008 A is divided by the fractional part of the unit (0.000001). The value of 0.0008 A is equal to 800 microamperes (μA; 0.0008 divided by 0.000001 = 800 μA).

When changing a basic electrical unit to a unit with a prefix, the decimal point of the number may be moved to the *right* by the same number of places represented by the prefix. To change 0.2 V to millivolts using this method, the decimal point in 0.2 V is moved three places to the right (0.200) since the prefix *milli* represents three decimal places. So 0.2 V equals 200 mV. This method may be used for converting any electrical unit to a unit with a prefix smaller than 1.

Electrical units with a prefix may easily be converted back to the basic unit. For example, milliamperes may be converted back to amperes, or microvolts may be converted back to volts. When a unit with a prefix is converted back to a basic unit, the prefix must be multiplied by the fractional part of the whole unit of the prefix. For example, 52 mV converted to volts is equal to 0.052 V. When 52 mV is multiplied by the fractional part

Prefix	Symbol	Factor by Which the Unit is Multiplied
exa	E	1,000,000,000,000,000,000 = 10^{18}
peta	P	1,000,000,000,000,000 = 10^{15}
tera	T	1,000,000,000,000 = 10^{12}
giga	G	1,000,000,000 = 10^{9}
mega	M	1,000,000 = 10^{6}
kilo	k	1,000 = 10^{3}
hecto	h	100 = 10^{2}
deka	da	10 = 10^{1}
deci	d	0.1 = 10^{-1}
centi	c	0.01 = 10^{-2}
milli	m	0.001 = 10^{-3}
micro	μ	0.000001 = 10^{-6}
nano	n	0.000000001 = 10^{-9}
pico	p	0.000000000001 = 10^{-12}
femto	f	0.000000000000001 = 10^{-15}
atto	a	0.000000000000000001 = 10^{-18}

Figure 1-2 SI standard prefixes.