INTRODUCTION to ELECTRONICS

Third Edition

Earl D. Gates

INTRODUCTION TO ELECTRONICS

A Practical Approach

Third Edition

Earl D. Gates

Delmar Publishers

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Cover Design: Susan Mathews, Stillwater Studio
Cover Image by Kari Kivisalo

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Printed in the United States of America

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Delmar Publishers
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Albany, New York 12212–5015

International Thomson Publishing Europe
Berkshire House 168-173
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London WC1V 7AA England

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South Melbourne, 3205
Victoria, Australia

Nelson Canada
1120 Birchmount Road
Scarborough, Ontario
Canada M1K 5G4

International Thomson Editores
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Col Polanco
11560 Mexico D F Mexico

International Thomson Publishing GmbH
Königswinterer Strasse 418
53227 Bonn Germany

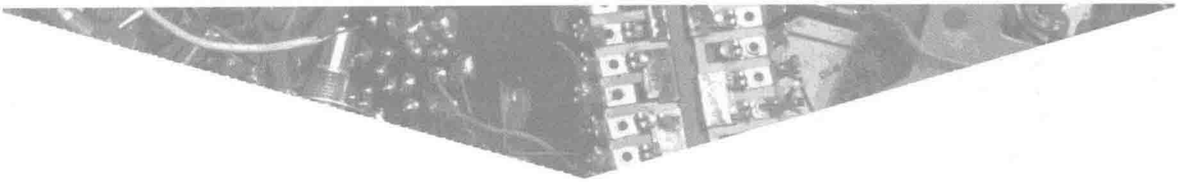
International Thomson Publishing Asia
221 Henderson Road
#05–10 Henderson Building
Singapore 0315

International Thomson Publishing-Japan
Hirakawacho Kyowa Building, 3F
2-2-1 Hirakawacho
Chiyoda-ku, Tokyo 102 Japan

4 5 6 7 8 9 10 XXX 10 00 99 98

Library of Congress Cataloging-in-Publication Data

Gates, Earl D., 1945–
Introduction to electronics : a practical approach / Earl D.
Gates. –– 3rd ed.
p. cm.
Includes index.
ISBN 0–8273–6789–9
1. Electronics. I. Title.
TK7816.G36 1997
621.381 –– dc21 96–47948
CIP



PREFACE

Several years ago I completed a survey with approximately twenty area electronics industries. From this study, I determined that industry wants a student graduating with a background in electronics to be able to:

- troubleshoot
- make various measurements with different pieces of test equipment, especially the oscilloscope
- be able to solder
- know where to find information
- know the references used in electronics

I found industry values the student's ability to *do* more than it values their ability to *know*. In short, I found that less time should be spent teaching theory and more time should be spent instructing hands-on applications.

The third edition of *Introduction to Electronics* continues to give students the basic background that more closely relates to the needs of industry. It provides the hands-on instruction required by industry along with the required theory. This text has been carefully developed and designed to make learning easier and teaching more efficient. It is intended to meet both the needs of a one-year program in electronics for high school, junior college, vocational and adult centers, and the needs for college. It is intended to be taught in a more exploratory fashion than for specific skill development. A three-semester sequence could emerge if a student focuses on DC and AC circuits the first semester, semiconductors and linear circuits the second semester, and digital circuits the third semester.

The following list provides some of the salient features of this text:

- Chapters are kept brief and focused.
- Objectives clearly state the learning goals at the beginning of each chapter.
- Illustrations are used generously to amplify the concepts learned.
- Review questions appear throughout each chapter so students may check their comprehension.
- The mathematical inclusions are written using only basic formulas.
- Frequent examples show math and formulas in use.
- Summaries at the end of each chapter review important concepts.
- Self-tests complete the learning tools for each chapter.
- The two-color design calls attention to the important features of this text.

Through a detailed reviewing process, the contents and organization of this text have been tailored to fit the current needs of students and teachers:

- A new and expanded introduction includes career exploration, using a calculator, and safety precautions.
- State-of-the-art graphic calculators are used for explanations.
- Numerous examples of real-life applications for the chapter materials are integrated.

This text is structured to provide a logical progression of material. However, because each chapter is a self-contained unit, the sequence may be varied to suit an appropriate teaching style.

I had a math teacher check the accuracy of all examples and self-test answers, and these examples were prepared with the assistance of this teacher. This approach creates examples that will help students correlate the math learned in mathematics class with the mathematics used in electronics.

In the lab, students transfer theory learned in class to hands-on practical applications. Therefore, a lab manual was developed to provide for this hands-on experience demanded by industry. Ambitious projects reinforce students' learning and help them see theory become practice. Many projects are available on the market that will provide the required reinforcement.

This textbook and the lab manual help students develop an interest in the field of electronics. A curriculum guide is included in the Instructor's Guide to serves as a foundation for a program in electronics.

I would like to thank Cheryl Scholand, a mathematics teacher, and Rolf Tiedemann, an electronics/technology education teacher, both of Greece Central School, whose help and support made this revision possible. I would also like to recognize the following people from the industry who continue to provide me with needed support: Gerald Buss, President of EIC Electronics, and Thomas Fegadel, Owner of Glenwood Sales.

Thanks are also due to the numerous teachers who use this text and have brought discrepancies to my attention and have identified areas to include or expand upon.

I would also like to thank the following reviewers for their valuable suggestions:

Tom S. Best
Glasgow High School
Glasgow, MO

Ronald J. Fronckowiak
Orleans Educational Center
Corfu, NY

Larry Goldberg
Rancho Santiago Community College
Santa Ana, CA

John Hammer
Rhinelander High School
Rhinelander, WI

Paul Jansson
Boise State University
School of Applied Technology
Boise, ID

Raymond Klein
Indiana Vocational Technical College
Gary, IN

Bruce Koller
Diablo Valley College
Pleasant Hill, CA

David Mixer
Leander High School
Leander, TX

Richard Rime
Dawson County High School
Glendive, MT

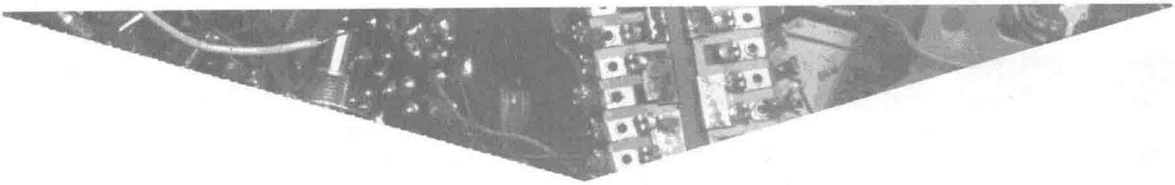
Bob Snider
Austin, TX

James Snively
Altoona Area Vo-Tech
Altoona, PA

Richard Steinmeier
Electronics Institute
Middletown, PA

Finally, I would like to thank my wife, Shirley; my daughters, Kimberly and Susan; and my son, Timothy, who have supported me in the development of this text.

Earl D. Gates
Rochester, NY
1997



CAREERS IN ELECTRONICS

Many exciting career opportunities exist in the electrical/electronics field. A sample of these available opportunities are provided in the following information. Check for other career opportunities at the career information center in your school or community.

Automation Mechanic

An automation mechanic maintains controllers, assembly equipment, copying machines, robots, and other automated or computerized devices. A person with this job installs, repairs, and services machinery with electrical, mechanical, hydraulic, or pneumatic components. Precision measuring instruments, test equipment, and handtools are used. A knowledge of electronics and the ability to read wiring diagrams and schematics are required.

Becoming an automation mechanic requires formal training which is offered by the military, junior/community colleges, vocational-technical schools, and in-house apprenticeship programs. Although most training is provided through formal classroom instruction, some of the training may only be obtained through on-the-job training.

Automation mechanic is one of the fastest growing vocations in the industry. This rapid growth is expected to continue through the year 2000.

Computer Technician

A computer technician installs, maintains, and repairs computer equipment and systems. Initially, the computer technician is responsible for laying cables and making equipment connections. This person must thoroughly test the new system(s), resolving all problems before the customer uses the equipment. At regular intervals, the computer technician maintains the equipment to ensure that everything is operating efficiently. A knowledge of basic and specialized test equipment and handtools is necessary.

Computer technicians spend much of their time working with people—listening to complaints, answering questions, and sometimes offering advice on both equipment system purchases and ways to keep equipment operating efficiently. Experienced computer technicians often train new technicians and sometimes have limited supervisory roles before moving into a supervisory or service managerial position.

A computer technician is required to have one or two years of training in basic electronics or electrical engineering from a junior college, college or vocational training center, or military installation. The computer technician must be able to keep up with all the new hardware and software.

Projections indicate that employment for computer technicians will be high through the year 2000. The nation's economy is expanding, so the need for computer equipment will increase; therefore, more computer technicians will be required to install and maintain equipment. Many job openings for computer technicians may develop from the need to replace technicians who leave the labor force, transfer to other occupations or fields, or move into management.

Electrical Engineer

Electrical engineers make up the largest branch of engineering. An electrical engineer designs new products, writes performance specifications, and develops maintenance requirements. Electrical engineers also test equipment and solve operating problems within a system, and predict how much time a project will require. Then, based on the time estimate, the electrical engineer determines how much the project will cost.

The electrical engineering field is divided into two specialty groups: electrical engineering and electronic engineering. An electrical engineer works in one or more areas of power-generating equipment, power-transmitting equipment, electric motors, machinery control, and lighting and wiring installation. An electronics engineer works with electronic equipment associated with radar, computers, communications, and consumer goods.

The number of engineers in demand is expected to increase through the year 2000. This projected growth is attributed to an increase in demand for computers, communication equipment, and military equipment. Additional jobs are being created through research and development of new types of automation and industrial robots. Despite this rapid growth, a majority of openings will result from a need to replace electrical and electronics engineers who leave the labor force, transfer to other occupations or fields, or move into management.

Electrician

An electrician may specialize in construction, maintenance, or both. Electricians assemble, install, and maintain heating, lighting, power, air-conditioning, or refrigeration components. The work of an electrician is active and sometimes strenuous. An electrician risks injury from electrical shock, falls, and cuts from sharp objects. To decrease the risk of these job-related hazards, an electrician is taught to use protective equipment and clothing to prevent shocks and other injuries. An electrician must adhere to the *National Electrical Code (NEC)®** specifications and procedures, as well as to the requirements of state, county, and municipal electric codes.

A large proportion of electricians are trained through apprenticeship programs. These programs are comprehensive, and people who complete them are qualified for both maintenance and construction work. Most localities require that an electrician be licensed. To obtain the license, electricians must pass an examination that tests their knowledge of electrical theory, the *National Electrical Code®*, and local electrical and building codes. After electricians are licensed, it is their responsibility to keep abreast of changes in the *National Electrical Code®*, with new materials, and with methods of installation.

Employment for an electrician is expected to increase through the year 2000. As population increases and the economy grows, more electricians will be needed to maintain the electrical systems used in industry and in homes.

Electronics Technician

Electronics technicians develop, manufacture, and service electronic equipment and they use sophisticated measuring and diagnostic equipment to test, adjust, and repair electronic equipment. This equipment includes radio, radar, sonar, television, and computers, as well as industrial and medical measuring and controlling devices.

One of the largest areas of employment for electronics technicians is in research and development. Technicians work with engineers to set up experiments and equipment, and calculate the results. They also assist engineers by making prototypes of newly developed equipment, as well as by performing routine design work. Some elec-

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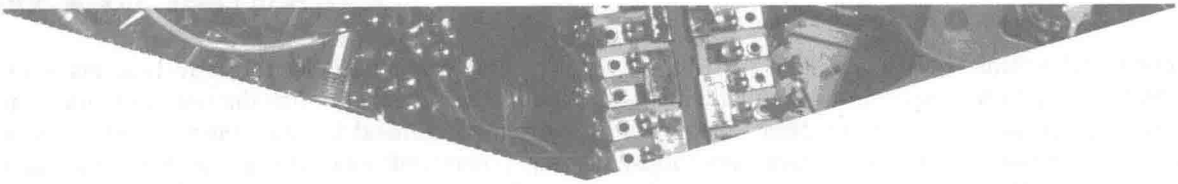
tronics technicians work as sales or field representatives to give advice on installation and maintenance of complex equipment. Most electronics technicians work in laboratories, electronics shops, or industrial plants. Ninety percent of electronics technicians work in private industry.

Becoming an electronics technician requires formal training, which is offered by the military, junior/community colleges, vocational-technical schools, or in-house apprenticeship programs.

Employment of electronics technicians is expected to increase through the year 2000 due to an increased demand for computers, communication equipment, military electronics, and electronic consumer goods. Increased product demand will provide job opportunities, but the need to replace technicians who leave the labor force, transfer to other occupatons or fields, or move into management may also increase.



USING A CALCULATOR

Due to a decrease in cost, the hand-held electronic calculator has become very popular. Many students have rejoiced that all of their mathematical work is now mastered. In just a few keystrokes, a calculator will give the correct answer. However, students fail to realize that a calculator is just a tool to perform calculations very quickly, but with no guarantees for a correct answer. A calculator gives the correct answer only when the correct numbers are entered, in the correct order, and with the correct function keys used at the appropriate time.

If operators do not understand principles of the mathematical process, they will not be able to properly enter data into a calculator, nor will they be able to correctly interpret the results. Mathematical skills still count. Even when all data is entered correctly, the answer may be incorrect due to battery failure, and so forth.

Selecting a calculator appropriate for electronics is an important decision. The marketplace is flooded with many makes and models. Which is the right one? What are the functions that will prove to be the most useful? For this course, choose one that has the following functions: +, −, ×, ÷, 1/x, x^2, and √. A memory function is optional. Scientific and programmable calculators have become popular. Although they are not needed for this course, they typically include formulas and functions used in trigonometry and statistics. If you decide to purchase one, study the manual carefully so you may use the calculator to its fullest extent. All calculators generally come with a manual, which should be kept handy.

The following examples show how a calculator is used to solve various types of problems in electronics. Turn on your calculator. Examine the keyboard. Let's do some calculating.

Addition

Example 1 Add: 39,857 + 19,733

Solution

Enter	Display
39857	39857
+	39857
19733	19733
=	59590

Subtraction

Example 2 Subtract: 30,102 − 15,249

Solution

Enter	Display
30102	30102
−	30102
15249	15249
=	14853

Multiplication

Example 3 Multiply: 33,545 × 981

Solution

Enter	Display
33545	33545
×	33545
981	981
=	32907645

Division

Example 4 Divide: 36,980 by 43 or $\frac{36,980}{43}$ or 43 ÷ 36,980

Solution

Enter	Display
36980	36980
÷	36980
43	43
=	860

Square Root

Example 5 Find the square root of 35,721

Solution

Enter	Display
35721	35721
√	189

Total Resistance (Parallel Circuit)

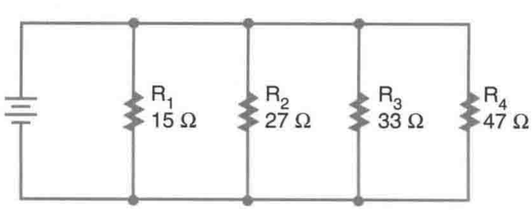
The total resistance of a parallel circuit may be calculated by first computing the reciprocal of each branch and then taking the reciprocal of the branch total.

Parallel circuits are made up of resistors that are sold in resistance values of ohms. Calculating parallel circuit total resistance involves the use of re-ciprocals (1/R) as shown in the parallel circuit formula:

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \cdots + \frac{1}{R_n}$$

A calculator gives the reciprocal of a number by simply pressing the 1/X key. If the calculator does not have a 1/X key, then each reciprocal value will be found separately by dividing 1 by the resistance value.

Example 6 Calculate the total equivalent resistance of the parallel circuit shown



Solution

	Enter	Display
Reciprocal of R_1	15	15
	1/X	0.0666667
Reciprocal of R_2	27	27
	1/X	0.037037
Reciprocal of R_3	33	33
	1/X	0.030303
Reciprocal of R_4	47	47
	1/X	0.0212766
	Enter	Display
Totals of reciprocals	0.0666667	0.0666667
	+	
	0.037037	0.1037037
	+	
	0.030303	0.1340067
	+	
	0.0212766	0.1552833
	Enter	Display
Reciprocal of totals	0.1552833	0.1552833
	1/X 6.4398425	Round answer to 6.44 Ω

Example 7 Using a Calculator with memory function

Solution

	Enter	Display
Reciprocal of R_1	15	15
	1/X	0.0666667
	M+	0.0666667 M
	C	0
Reciprocal of R_2	27	27
	1/X	0.037037
	M+	0.037037 M
	C 0	
Reciprocal of R_3	33	33
	1/X	0.030303
	M+	0.030303 M
	C	0
Reciprocal of R_4	47	47
	1/X	0.0212766
	M+	0.0212766 M
	C	0
Totals of reciprocals	RM	0.0.155283329
Reciprocal of totals	1/X	6.439841299
		Round answer to 6.44 Ω

Rounding

Note: Rounding is not a calculator function and must be done mentally. The number of significant digits can be reduced by *rounding off*. This means dropping the least significant digits until the desired number of digits remain. The new least significant digit may be changed using the following rules:

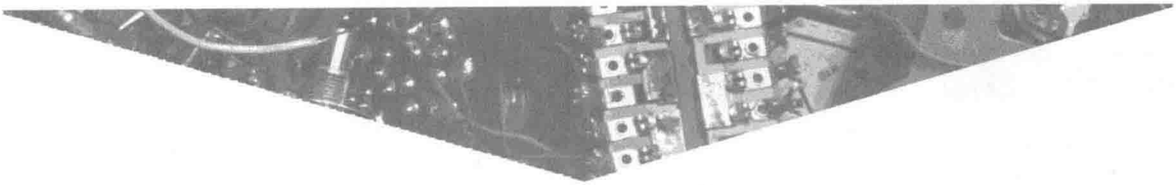
If the highest significant digit dropped is

- less than 5, the new significant digit is not changed.
- greater than 5, the new significant digit is increased by one.
- 5, the new significant digit is not changed if it is even.
- 5, the new significant digit is increased by one if it is odd.

Example Round 352.580

Round to the nearest tenth	352.6
Round to the nearest whole number	352
Round to the nearest hundred	400

These rules result in a rounding off technique that on the average gives the most consistent reliability.



SAFETY PRECAUTIONS

The following safety precautions are not intended as a replacement for information given in class or lab manuals. If at any time you question what steps or procedures to follow, consult your teacher.

General Safety Precautions

Because of the possibility of personal injury, danger of fire, and possible damage to equipment and materials, all work on electrical and electronic circuits should be conducted following these basic safety precedures.

1. *Remove power from the circuit or equipment prior to working on it.* Never override interlock safety devices. Never assume the circuit is off; check it with a voltmeter.
2. *Remove and replace fuses only after the power to the circuit has been deenergized.*
3. *Make sure all equipment is properly grounded.*
4. *Use extreme caution when removing or installing batteries containing acid.*
5. *Use cleaning fluids only in well-ventilated spaces.*
6. *Dispose of cleaning rags and other flammable materials in tightly closed metal containers.*
7. *In case of an electrical fire, deenergize the circuit and report it immediately to the appropriate authority.*

High Voltage Safety Precautions

As people become familiar with working on circuits, it is human nature to become careless with routine procedures. Many pieces of electrical equipment use voltages that are dangerous and can be fatal if contacted. The following precautions should be followed at all times when working on or near high voltage circuits:

1. *Consider the result of each act.* There is absolutely no reason for individuals to take chances that will endanger their life or the lives of others.
2. *Keep away from live circuits.* Do not work on or make adjustments with high voltage on.
3. *Do not work alone.* Always work in the presence of another person capable of providing assistance and first aid in case of an emergency. People who are considering a career working in the electricity and electronics field should become CPR certified.
4. *Do not tamper with interlocks.*
5. *Do not ground yourself.* Make sure you are not grounded when making adjustments or using measuring instruments. Use only one hand when connecting equipment to a circuit. Make it a practice to put one hand in your rear pocket.
6. *Never energize equipment in the presence of water leakage.*

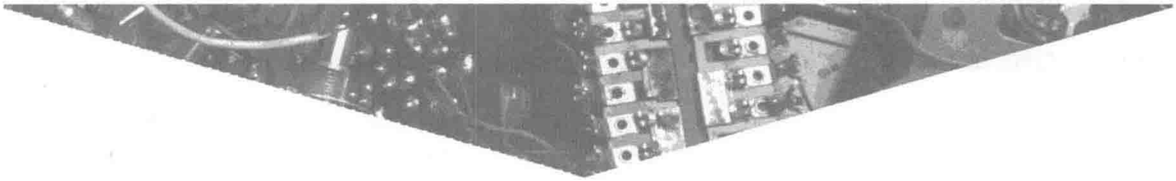
Personal Safety Precautions

Take time to be safe when working on electrical and electronic circuits. Do not work on any circuits or equipment unless the power is secured.

1. *Work only in clean dry areas.* Avoid working in damp or wet locations because the resistance of the skin will be lower; this increases the chance of electrical shock.
2. *Do not wear loose or flapping clothing.* Not only may it get caught, but it might also serve as a path for the conduction of electricity.
3. *Wear only nonconductive shoes.* This will reduce the chance of electrical shock.
4. *Remove all rings, wristwatches, bracelets, ID chains and tags, and similar metal items.* Avoid clothing that contain exposed metal zippers, buttons, or other types of metal fasteners. The metal can act as a conductor, heat up and cause a bad burn.
5. *Do not use bare hands to remove hot parts.*
6. *Use a shorting stick to remove high voltage charges on capacitors.* Capacitors can hold a charge for long periods of time and are frequently overlooked.
7. *Make certain that the equipment being used is properly grounded.* Ground all test equipment to the circuit and/or equipment under test.
8. *Remove power to a circuit prior to connecting alligator clips.* Handling uninsulated alligator clips could cause potential shock hazards.
9. *When measuring voltages over 300 volts, do not hold the test prods.* This eliminates the possibility of shock from leakage on the probes.

Safety is everyone's responsibility. It is the job of everybody in and out of class to exercise proper precautions to insure that no one will be injured and no equipment will be damaged.

Every class in which you work should emphasize and practice safety.



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