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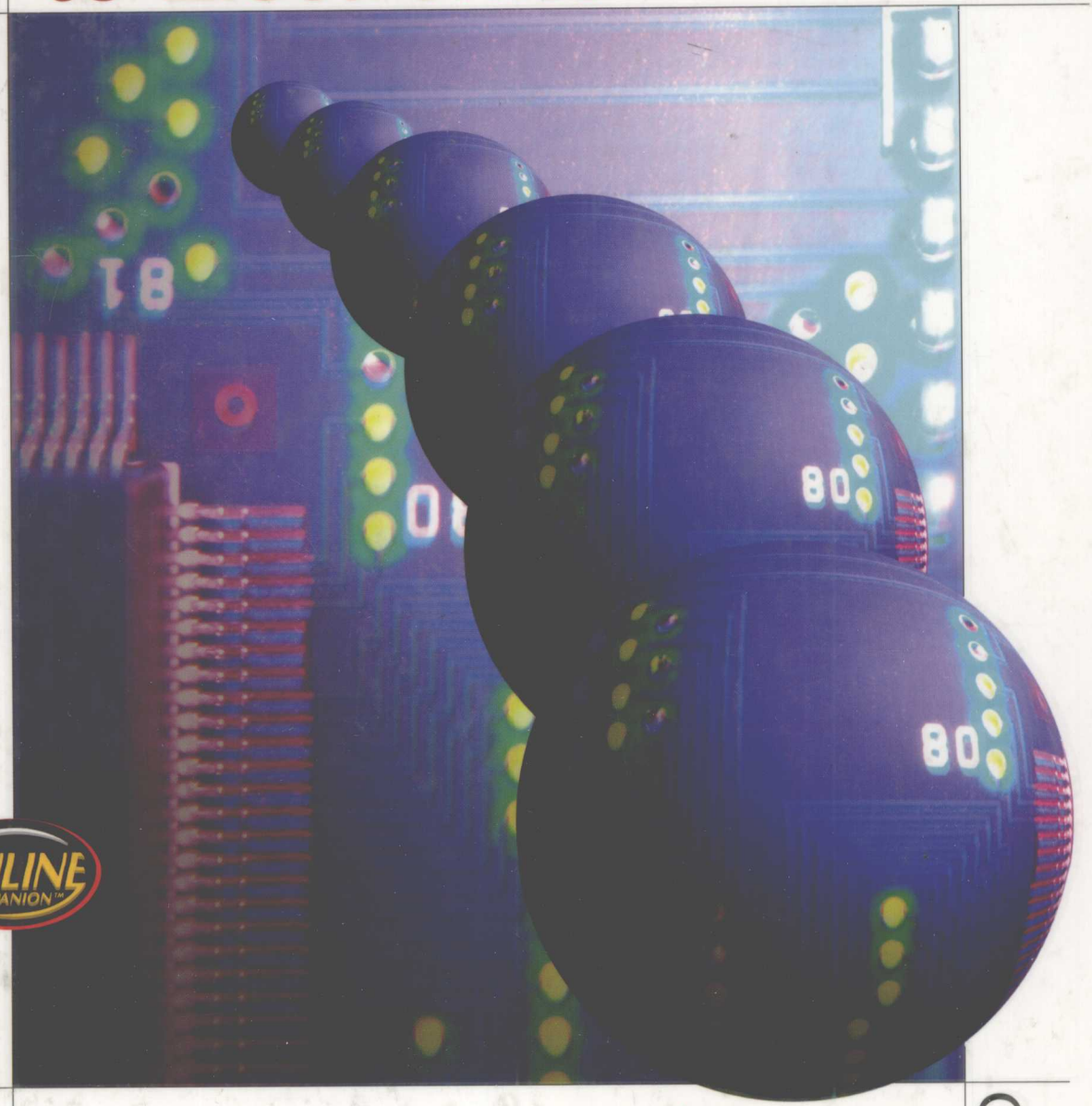
Introduction to Electronics



ONLINE COMPANION™

4th edition

Gates

INTRODUCTION TO ELECTRONICS

Fourth Edition

Earl D. Gates

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Australia Canada Mexico Singapore Spain United Kingdom United States

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Introduction to Electronics
Fourth Edition
Earl D. Gates

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For more information contact Delmar Learning, Executive Woods, 5 Maxwell Drive, PO Box 8007, Clifton Park, NY 12065-8007.
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PREFACE

Intended Audience

Introduction to Electronics is intended to meet the needs of a one-year program in electronics for high schools, vocational schools, career colleges, and community colleges. The book may also be used in a survey course in electronics for electronics technology, computer technology, and telecommunications. The fourth edition 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.

Background of This Book

This fourth edition has the same objectives as the three previous editions, namely, to provide a text and reference book that summarizes in understandable terms those principles and techniques, that are the basic tools of electronics. In keeping with current trends, increased emphasis is placed on the general techniques of electronics. During my teaching in public school I completed a study on what industry wanted from students graduating with a background in electronics. I found that industry valued a student's ability to *do* more than they valued their ability to *know*. I found that industry wanted less time spent on teaching theory and more time spent on instructing hands-on applications.

After I had rewritten my curriculum, I found I had to use several textbooks to teach it. I originally wrote the first edition of *Introduction to Electronics* to provide the students with all the information required by the curriculum in one easy-to-use textbook. The fourth edition continues to refine the needs of the students through input from teachers and changes from the electronics field.

Textbook Organization

Due to the rapid growth of electronics, it becomes impossible to cover all of the important topics in a one-year course. *Introduction to Electronics* provides the faculty with an opportunity to select those topics that he/she wishes to emphasize and, at the same time, provide the student with a reference book of basic electronics coverage and continuing value.

Teacher can guide students to concentrate on the material related to a particular course syllabus, leaving the remaining subject matter as enrichment should students wish to extend their knowledge at a future date. Alternatively, the faculty can choose to cover a series of selected topics, such as DC and AC circuits. Another possibility is to concentrate on the material related primarily to linear electronics circuits or other topic of choice. Many other combinations are possible.

The emphasis still continues to be coverage of electronics combined with a presentation that allows the student to study a particular topic without having to read the entire text. The level of the presentation remains unchanged.

The book is divided into five distinct sections:

Section 1—DC Circuits discusses current, voltage, resistance, Ohm's Law, measurement, power, DC circuits, magnetism, inductance, and capacitance.

Section 2—AC Circuits covers alternating current, AC measurements, resistive AC circuits, capacitive AC circuits, inductive AC circuits, resonance circuits, and transformers.

Section 3—Semiconductor Devices covers topics on PN junction diodes, zener diodes, bipolar transistors, FETs, thyristors, integrated circuits, and optoelectronic devices.

Section 4—Linear Electronic Circuits covers topics on power supplies, amplifier basics, amplifier applications, oscillators, and waveshaping circuits.

Section 5—Digital Electronic Circuits covers binary number system, basic logic gates, sequential and combinational logic circuits, and microcomputer basics.

A **Glossary** contains key terms and definitions. Finally, the **Appendix** includes additional helpful reference material.

Features

The following list provides some of the salient features of the 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.
- Numerous examples of real-life applications for the chapter materials are integrated.
- Section activities offer optional hands-on projects to reinforce concepts.

To ensure accuracy of the examples and problems, a mathematics teacher continues to review and simplify them. As in previous editions, this approach creates examples that will help students correlate the math learned in mathematics classes with the math used in electronics.

New Features to This Edition:

To keep pace with the rapidly changing technology, new material has been added to appropriate chapters.

- 
  A new CD includes MultiSIM circuit files of selected figures from the textbook. Each circuit file includes a schematic and supporting narrative that provides information on troubleshooting and simulating the circuit.
- New and updated photos display images of components and equipment to support theoretical concepts.
- New Career Profiles highlight occupations of specific individuals and show the many fields students can pursue in electronics.
- New full-color insert reflects industry standards and highlights the process of creating an integrated circuit.
- New Section Activities include optional hands-on projects that encompass the use of breadboards and computer simulation programs.
- Chapter 4 (Resistance) includes expanded coverage of surface mount technology and keeps pace with changes in industry.
- Chapter 5 (Ohm's Law) adds coverage of Kirchoff's Current Law and Voltage Law to help students analyze circuits.
- Chapter 6 (Electrical Measurements—Meters) covers new material on testing and instrumentation, and covers digital equipment in more depth.
- Chapter 8 (DC Circuits) discusses the importance of voltage dividers, which are used in common, everyday circuits.
- Chapter 12 (Alternating Current) discusses how an AC distribution system works and how it is used in today's society.
- Chapter 13 (AC Measurements) includes added material on the Bode Plotter to help analyze circuits in MultiSIM.
- Chapter 34 (Simplifying Logic Circuits) covers new material on Karnaugh maps.
- Chapter 35 (Sequential Logic Circuits) adds material on memory to help understand

computer systems.
- Chapter 36 (Combinational Logic Circuits) covers new material on programmable logic devices and keeps up-to-date with digital technology.
- Chapter 36 (Microcomputer Basics) exposes students to current technology in microcontrollers, which is used in everyday applications.

Using the CD-ROM

The accompanying CD includes a free Textbook Edition of MultiSIM and MultiSIM™ (circuit files. Students can use these precreated files for troubleshooting and simulation. Textbook figures created as MultiSIM files are identified by a CD icon throughout the text.

The Learning Package

The complete ancillary package was developed to achieve two goals:

1 To assist students in learning the essential information needed to prepare for the exciting field of electronics.
2 To assist instructors in planning and implementing their instructional programs for the most efficient use of time and other resources.

Lab Manual. Labs provide students with the opportunity to transfer theory provided in class to hands-on practical applications. Projects serve to reinforce the student's learning, providing them the opportunities to see theory become practice. (ISBN: 0-7668-1700-8)

Instructors' Guide. The Instructor's Guide contains solutions to end-of-chapter textbook questions and to the lab manual experiments. To assist the instructor/teacher in preparing their program, a curriculum guide is provided in the Instructor's Guide. It helps them to provide a program that will develop a student's interest in the field of electronics. (ISBN: 0-7668-1699-0)

e.resource. The *e.resource* is an educational resource that creates a truly electronic classroom. It is a CD-ROM containing tools and instructional resources that enrich your classroom and make your preparation time shorter. The elements of *e.resource* link directly to the text and tie together to provide a unified instructional system. With the *e.resource,* you can spend your time teaching, not preparing to teach. (ISBN: 0-7668-3017-9)

Features contained in the *e.resource* include:

PowerPoint Presentation. These slides provide the basis for a lecture outline that helps you to present concepts and material. Key points and concepts can be graphically highlighted for student retention. There are 480 slides, covering every chapter in the text.

Computerized Testbank: Over 900 questions in multiple-choice format so you can assess student comprehension.

Image Library. Over 200 images from the textbook to create your own transparency masters or to customize your own PowerPoint slides. The Image Library comes with the ability to browse and search images with key words and allows quick and easy use.

Online Companion

The text has a companion website at *www.electronictech.com,* which will have high appeal to both educators and students. The Online Companion provides access to text updates, online quizzes, RealAudio broadcasts and more.

About the Author

The author is an Associate Professor at the State University of New York College at Oswego where he teaches Electronics Technology in the Depart-

ment of Technology. He has 23 years' experience in public education as a successful teacher and administrator.

The author spent approximately 10 years in the US Navy as an Electronics Technician, supervising, servicing, maintaining, and teaching the digital navigation computers on Fleet Ballistic Missile Submarines. He additionally spent another 19 years in the US Naval Reserves as an Electronics Technician before retiring in 1998 as a Senior Chief.

He is a member of many professional organizations including: the International Technology Education Association (ITEA), New York State Technology Education Association (NYSTEA), and the International Graphic Arts Education Association (IGAEA).

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Earl D. Gates
Oswego, New York
2001

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 2006.

Automotive Mechanic

There are currently more computers aboard today's automobile than aboard our first spaceship. A typical automobile contains approximately ten to fifteen computers that operate everything from the engine and radio to the driver's seat. As a result, automotive mechanics now need a greater knowledge of electronics.

To be able to distinguish an electronic malfunction from a mechanical malfunction, automotive mechanics must be familiar with the minimum of the basic principles of electronics. In addition, they must be able to test and replace electronic components.

Becoming an automotive 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 be obtained only through on-the-job training. To reduce the amount of time invested in training a prospective mechanic, more employers are now looking for people who have completed a formal automotive training program.

Employment opportunities are good for automotive mechanics who have completed an automotive training program. People whose training includes basic electronics skills will have the best opportunities. Employment growth is expected to increase at a normal rate through the year 2006 with a concentration in automobile dealerships, independent automotive repair shops, and specialty car-care chains. Employment in gasoline service stations will continue to decline as fewer stations will offer repair services.

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 2006. 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.

Computer Engineers

The rapid growth in computers has generated a demand for people trained in designing new hardware and software systems and incorporating new technologies into existing and new systems. These trained professionals are known as computer engineers and system analysts.

Computer engineers can be further broken down into hardware and software engineers. Computer hardware engineers design, develop, test, and supervise the manufacturing of computer hardware. Computer software engineers design and develop software systems for control and automation of manufacturing, business, and management processes. They also may design and develop software applications for consumer use at home or create custom software applications for clients.

There is no universally accepted preparation for a computer professional because the job often depends on the work that needs to be done. Most employers require that employees have at least a bachelor's degree. However, a passion for computers and proficiency in advanced computer skills will at times win out over a bachelor's degree.

This field is one of the fastest-growing fields through the year 2006. Technological advances are occurring so rapidly in the computer field that employers are struggling to keep up with trained professionals. As the technology becomes more sophisticated and complex, more expertise and a higher level of skills will be required. A continual learning process must be undertaken to keep up. College graduates with a bachelor's degree in computer science, computer engineering, information science, or information systems will enjoy favorable employment opportunities.

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 2006. 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 industrial robot control systems and aviation electronics. 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.

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Employment for an electrician is expected to increase through the year 2006. As population increases and the economy grows, more electricians will be needed to maintain the electrical systems used in industry and in homes. Additionally, as both new and old homes are prepared for new technologies to make them smarter, the demand will require more electricians who are trained in the new technologies.

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 electronics 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 2006 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 $\sqrt{}$. 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
$\sqrt{}$	189

Total Resistance (Parallel Circuit)

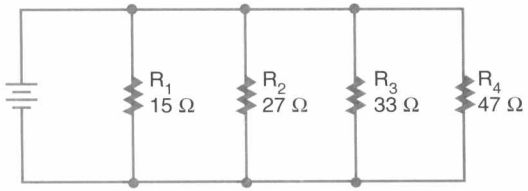
The total resistance of a parallel circuit may be calculated by first computing the reciprocal of each branch and then taking the reciprocal of the branch total.

Parallel circuits are made up of resistors that are sold in resistance values of ohms. Calculating parallel circuit total resistance involves the use of reciprocals (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. *Use an isolation transformer when working on AC powered circuit/equipment.* An isolation transformer isolates the circuit/equipment from the power source, adding an additional safety factor.
7. *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 with polarized plugs.* 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.

Fire Safety

There are three categories of fire, with each requiring special extinguishing techniques.

Class A	Combustible materials such as wood, paper, or cloth. Extinguish this type of fire by cooling it with water or smothering it with a CO_2 (Carbon Dioxide) extinguisher.
Class B	Flammable liquids such as gasoline, kerosene, greases, or solvents. Extinguish by smothering with foam or CO_2 extinguisher.
Class C	Electrical equipment. Extinguish by removing power source and use nonconducting dry power or CO_2 extinguisher.

Electrical Shock

A major hazard when working with electricity and electronic circuits is electrical shock. Electrical shock occurs when an electric current flows through the body when a complete circuit exists. Different levels of current produce the following results:

0.001 Ampere (1 mA)	A mild tingling sensation that can be felt.
0.010 Ampere (10 mA)	Start to lose muscular control.
0.030 Ampere (30 mA)	Breathing becomes upset and labored. Muscular paralysis.
0.100 Ampere (100 mA)	Death if the current lasts for more than a second.
0.200 Ampere (200 mA)	Severe burns, breathing stops. Death.

One technique to reduce current flow is to increase body resistance. Body resistance is high when the skin moisture content is low with no cuts or abrasions at the point of electrical contact. In these situations, very little current will flow with a mild shock resulting.

If the situation were reversed with high skin moisture content, lowering the body resistance, a large current would flow. If the current flows through the chest region, the heart could go into ventricular fibrillation resulting in rapid and irregular muscle contractions, leading to cardiac arrest and breathing stops.

The factors that influence the effects of electrical shock include:

- Intensity of the current.
- Frequency of the current
- Current path through the body
- Length of time current passes through the body

Remember, it is the amount of current flow through the body, not the amount of voltage contacted, that determines the severity of a shock. The larger the current through the body, the greater the effect of the shock.

First Aid

With severe electrical shock, do not become part of the problem. First, send for help; then remove the source of power. Do not attempt to touch or pull the victim away without removing the power souce or you will also get yourself shocked.

If the power source cannot be secured, use a nonconducting material to remove the victim from the circuit. Once the victim is free, check for signs of breathing and pulse. If trained, begin CPR (cardiopulmonary resuscitation) if necessary.

When electrical shock is not life threatening, keep the victim calm and send for expert medical help.

Hazardous Chemicals

Concerns with hazardous chemicals include breathing vapors, contact with skin and eyes, injecting liquids, and danger of fire or explosions. Chemicals found in the electronics laboratory include: adhesives, cleaning solvents, etching solutions, photographic developing solutions, screenprinting developing and cleaning solutions, solder fumes, and spray paints.

Observe the following safety practices when working with chemicals:

1. Always wear safety glasses when working with hazardous chemicals.
2. Wear protective rubber/vinyl gloves when working with acids.
3. Use tongs when handling printed circuits being etched.
4. Read the label on all chemicals being used.
5. Work in a well-ventilated space.
6. Wash all tools that contact any hazardous chemical.
7. Always label containers with chemicals.
8. Do not store chemicals in glass containers if possible.
9. Store all chemicals in a flammable metal storage cabinet.

In case of contain with a hazardous chemical, read the label and follow instructions and send for expert medical help.

Electrostatic Discharge (ESD)

Static electricity is an electrical charge at rest on a surface. The static charge becomes larger through the action of a contact and separation or by motion. The electrostatic discharge takes place when the charged body comes near or touches a neutral surface.

A surface can become charged through three means. The most common means is an electrical charge generated by friction. Rubbing two dissimilar materials together will generate an electrical charge. Walking across a floor or removing a garment will develop a voltage in excess of 5000 volts. It takes approximately 5000 volts to jump approximately 1/4 of an inch.

Induction is a second means of developing a charge. When a person handles a printed circuit board or electronic component wrapped in a plastic material, they induce a charge into the contents of the plastic wrap. When another person removes the plastic wrap, the sudden discharge results in ESD damage.

Capacitance is the third means of generating a static charge. Capacitance is inversely related to the distance between two surfaces. A low voltage can become harmful as one surface is removed further from the other surface or ground. When a circuit is picked up from a table its relative capacitance decreases and voltage increases. When the circuit is grounded again, damage will occur by the large voltage discharging that was generated when the circuit was originally lifted.

Metal Oxide Semiconductors (MOS) are extremely sensitive to static charges, as are CMOS, FETs, VLSI ICs, NMOS, PMOS, Schottky diodes, ECL and linear ICs devices.

High humidity can increase surface conductivity, which reduces friction-generated static electricity. The increased humidity spreads the charge over a larger surface area, reducing the field intensity, and allows the charge to bleed off to ground.

Manufacturers have designed protective circuitry to help dissipate ESD using zener diodes and limiting resistors.

ESD prevention requires the awareness and practice of the following procedures:

1. Treat all electronic components and circuits as static sensitive.
2. Do not touch the leads or pins or components or printed circuit board traces.
3. Before handling a component or circuit, discharge yourself by touching a grounded metal surface.
4. Keep components in original packing materials until needed.
5. Never slide static components over any surface.

Hand Tools

When using hand tools, always observe the following precautions:

1. Always use the proper tool for the job. Use the right type and size tool for each application.

2. When carrying tools, always keep the cutting edge down.
3. Keep hands clean when using tools. Avoid grease, dirt, or oil on hands when using any tool.
4. Clamp small pieces when using hacksaw, screwdriver, or soldering iron.
5. Avoid using chisels and punches with mushroomed heads.
6. Never use a file without a handle.
7. Never use plastic-handled tools near an open flame.
8. Keep metal rules clear of electrical circuits.
9. Disconnect all electrical devices by pulling directly on the plug, never the cord.
10. When cutting wire, always cut one wire at a time to avoid damaging the cutting tool.

Power Tools

When using power tools, always observe the following precautions:

1. Only the operator starts or stops a machine. When stopping a machine, wait until it comes to a complete stop before leaving the machine.
2. Make all adjustments to the machine prior to turning it on.
3. Never have any loose hand tools, rags, or brushes in the work area when applying power.
4. Keep all safety guards in their proper position at all times.
5. Never force a cutting or drilling tool into a workpiece.
6. Only one person in the work zone at all times power is applied.
7. Have instructor check any special setups prior to applying power.
8 Use only grounded power tools with three-prong plugs or UL (Underwriters Laboratories) -approved housing power tools.

Soldering

When soldering, always observe the following precautions:

1. Always assume the soldering iron is hot. Never touch the tip to see if it is hot.
2. Always place the soldering iron in its holder when idling.
3. Never shake excess solder off the tip; wipe it on a damp sponge or approved tip cleaner.
4. Never pass a soldering iron to another person; place in the holder and let the other person take it from there.
5. Never solder on a circuit that has power applied to it.
6. Always use a grounded-tip soldering iron.

Standards

Underwriters Laboratories (UL) label on a device implies the product bearing the label is safe for use as intended. Tests completed by Underwriters Laboratories determine if a product meets the minimum safety standards. When purchasing a product, check to determine if it has the UL label on it. The UL label has nothing to do with the quality of a product – only the safety of it.

The Canadian Standard Association (CSA) is similar to the UL safety test. It also has very strict safety codes. The CSA label appears on all types of products, including electrical products. CSA also does on-site inspections of manufacturers on a frequent basis.

If a device has both the UL and CSA labels on it, it can be assumed that the device is safe.

A number of insurance companies have formed a group known as the National Fire Protection Association. Every few years, this group publishes a summary of electrical-wiring codes under the general heading of the National Electrical Code (NEC). The purpose of this code is to provide guidelines for safe wiring practices in residential and commercial buildings. State and local municipalities may require even more stringent codes than the NEC that must be followed. In many states all wiring must be done or approved by a master electrician. These codes are published for both your own and your neighbor's protection. Electrical fires can and do happen and they can spread to adjacent homes or apartments. The NEC guidebook helps to minimize electrical fires and to provide safety when doing electrical wiring.

CONTENTS