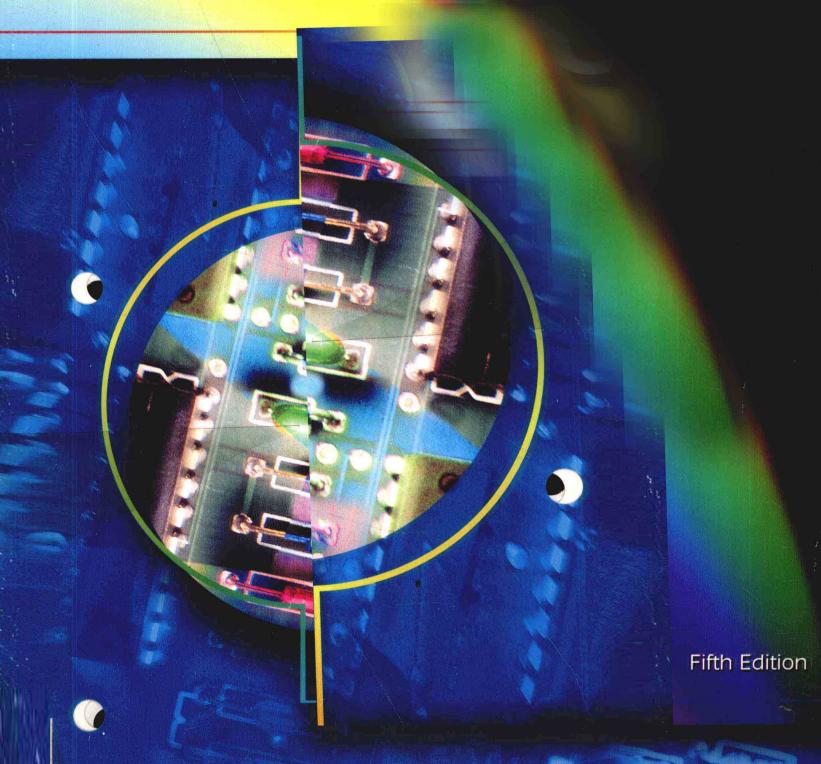
EXPERIMENTS MANUAL FOR

ELECTRONICS

Principles and Applications



Schuler

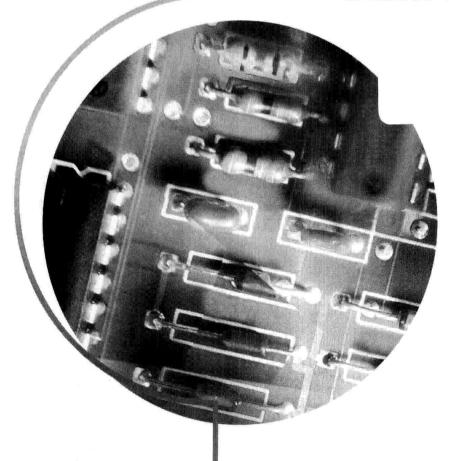
Basic Skills in Electricity and Electronics

ELECTRONICS

Principles and Applications

Fifth Edition

Charles A. Schuler





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Experiments Manual for

Electronics: Principles and Applications, Fifth Edition

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The Glencoe Basic Skills in Electricity and Electronics series has been designed to provide entry-level competencies in a wide range of occupations in the electrical and electronic fields. The series consists of coordinated instructional materials designed especially for the careeroriented student. Each major subject area covered in the series is supported by a textbook, an experiments manual, and an instructor's productivity center. All the materials focus on the theory, practices, applications, and experiences necessary for those preparing to enter technical careers.

There are two fundamental considerations in the preparation of materials for such a series: the needs of the learner and needs of the employer. The materials in this series meet these needs in an expert fashion. The authors and editors have drawn upon their broad teaching and technical experiences to accurately interpret and meet the needs of the student. The needs of business and industry have been identified through personal interviews, industry publications, government occupational trend reports, and reports by industry associations.

The processes used to produce and refine the series have been ongoing. Technological change is rapid and the content has been revised to focus on current trends. Refinements in pedagogy have been defined and implemented based on classroom testing and feedback from students and instructors using the series. Every effort has been made to offer the best possible learning materials.

The widespread acceptance of the Basic Skills in Electricity and Electronics series and the positive responses from users confirm the basic soundness in content and design of these materials as well as their effectiveness as learning tools. Instructors will find the texts and manuals in each of the subject areas logically structured, well-paced, and developed around a framework of modern objectives. Students will find the materials to be readable, lucidly illustrated, and interesting. They will also find a generous amount of self-study and review materials and examples to help them determine their own progress.

Both the initial and on-going success of this series are due in large part to the wisdom and vision of Gordon Rockmaker who was a magical combination of editor, writer, teacher, electrical engineer, and friend. Gordon has retired but he is still our friend. The publisher and editors welcome comments and suggestions from instructors and students using the materials in this series.

Charles A. Schuler, Project Editor and Brian P. Mackin, Editorial Director

Basic Skills in Electricity and Electronics

Charles A. Schuler, Project Editor

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Industrial Electronics, Frank D. Petruzella
Mathematics for Electronics, Harry Forster, Jr.



This manual provides comprehensive chapter tests and lab experiments. Its content runs parallel to the theory presented in the fifth edition of *Electronics: Principles* and Applications. Students will find that applying theory and working with circuits will enhance their understanding and make it easier for them to remember details. This edition more than doubles the number of experiments found in the last edition. Many of the additional experiments are based on software simulation, and some lend themselves to both laboratory breadboarding and simulation. The software simulations are optional. Other experiments offer problems and design examples. Everything in this manual fosters the development of the kinds of skills and knowledge used by practicing electronic technicians.

The experiments are a very important part of this manual. Their intention is not merely to have students read instruments and record data. Although these skills are essential, they are not the final objective. Each experiment is designed to demonstrate the concepts and principles of analog electronic circuits. They also show practical ways in which devices and circuits are used. The data collected by the student has value because it serves as a vehicle for learning. If data is merely numbers, it is useless. Students are encouraged to look for meaning in their data, to verify trends, and to solve for values whenever possible.

This edition includes many new, open-ended lab experiments. In these, the procedure and data-collection process are not greatly detailed. These experiments are provided in response to the many instructors who requested flexibility and expressed a need to place more responsibility on students. The second impetus for the inclusion of this type of experiment arises from the worldwide movement toward quality standards such as ISO9000. When organizations embrace such standards, there is an increased need for quality documentation. The work of technicians certainly does not escape the

impact of this development. Consequently, the lab notebook policies of many organizations are now more stringent than ever before. (The reader is encouraged to consult Appendix C in this manual for guidelines.) The third impetus for the use of the open-ended lab experiment is the need for collaborative learning. You will find specific examples of how the entire class can become involved in experimental work. This involvement will enchance the learning process and emphasize how teamwork comes about in the workplace.

The experiments in this manual span a wide range of electronic applications. The content progresses from basic concepts to advanced applications. Students will learn how to lay out and wire circuits using schematic diagrams. There is new appendix material on breadboarding to support this work (see Appendix B). Students will apply color codes, read and interpret symbols, and learn about the physical arrangement of components. They will use common instruments to measure electrical quantities, verify proper circuit operation, and interpret their results. They will analyze data and develop insight into circuit behavior. They can use optional software simulations to investigate circuit behavior and gain troubleshooting experience. All the activities have one central goal: to develop the skills and knowledge needed to pursue a technical career in the field of electronics.

Every effort has been made to develop experiments that support modern theory and also have a strong link to current practices. Based on feedback from the earlier editions, it has been possible to expand the number of experiments without adding to the component inventory. I would enjoy hearing from both instructors and students about the experiments in the fifth edition.

Charles A. Schuler



Electric and electronic circuits can be dangerous. Safe practices are necessary to prevent electrical shock, fires, explosions, mechanical damage, and injuries resulting from the improper use of tools.

Perhaps the greatest hazard is electrical shock. A current through the human body in excess of 10 milliamperes can paralyze the victim and make it impossible to let go of a "live" conductor or component. Ten milliamperes is a rather small amount of electrical flow: It is only ten one-thousandths of an ampere. An ordinary flashlight uses more than 100 times that amount of current!

Flashlight cells and batteries are safe to handle because the resistance of human skin is normally high enough to keep the current flow very small. For example, touching an ordinary 1.5-V cell produces a current flow in the microampere range (a microampere is one-millionth of an ampere). This amount of current is too small to be noticed.

High voltage, on the other hand, can force enough current through the skin to produce a shock. If the current approaches 100 milliamperes or more, the shock can be fatal. Thus, the danger of shock increases with voltage. Those who work with high voltage must be properly trained and equipped.

When human skin is moist or cut, its resistance to the flow of electricity can drop drastically. When this happens, even moderate voltages may cause a serious shock. Experienced technicians know this, and they also know that so-called low-voltage equipment may have a high-voltage section or two. In other words, they do not practice two methods of working with circuits: one for high voltage and one for low voltage. They follow safe procedures at all times. They do not assume protective devices are working. They do not assume a circuit is off even though the switch is in the OFF position. They know the switch could be defective.

As your knowledge and experience grow, you will learn many specific safe procedures for dealing with electricity and electronics. In the meantime:

- 1. Always follow procedures.
- 2. Use service manuals as often as possible. They often contain specific safety information. Read,

- and comply with, all appropriate material safety data sheets.
- 3. Investigate before you act.
- 4. When in doubt, *do not act*. Ask your instructor or supervisor.

General Safety Rules for Electricity and Electronics

Safe practices will protect you and your fellow workers. Study the following rules. Discuss them with others, and ask your instructor about any you do not understand.

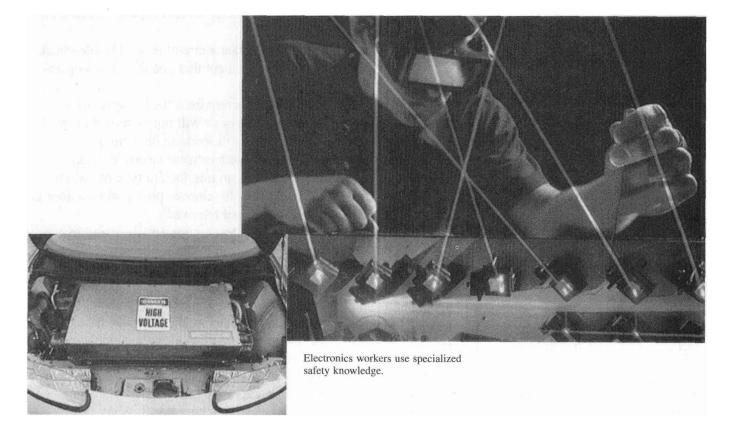
- 1. Do not work when you are tired or taking medicine that makes you drowsy.
- 2. Do not work in poor light.
- Do not work in damp areas or with wet shoes or clothing.
- 4. Use approved tools, equipment, and protective devices.
- Avoid wearing rings, bracelets, and similar metal items when working around exposed electric circuits.
- 6. Never assume that a circuit is off. Double-check it with an instrument that you are sure is operational.
- 7. Some situations require a "buddy system" to guarantee that power will not be turned on while a technician is still working on a circuit.
- 8. Never tamper with or try to override safety devices such as an interlock (a type of switch that automatically removes power when a door is opened or a panel removed).
- 9. Keep tools and test equipment clean and in good working condition. Replace insulated probes and leads at the first sign of deterioration.
- 10. Some devices, such as capacitors, can store a *lethal* charge. They may store this charge for long periods of time. You must be certain these devices are discharged before working around them.
- 11. Do not remove grounds and do not use adaptors that defeat the equipment ground.
- 12. Use only an approved fire extinguisher for electrical and electronic equipment. Water can con-

duct electricity and may severely damage equipment. Carbon dioxide (CO₂) or halogenated-type extinguishers are usually preferred. Foam-type extinguishers may also be desired in *some* cases. Commercial fire extinguishers are rated for the type of fires for which they are effective. Use only those rated for the proper working conditions.

- 13. Follow directions when using solvents and other chemicals. They may be toxic, flammable, or may damage certain materials such as plastics. Always read and follow the appropriate material safety data sheets.
- 14. A few materials used in electronic equipment are toxic. Examples include tantalum capacitors and beryllium oxide transistor cases. These devices should not be crushed or abraded, and you should wash your hands thoroughly after handling them. Other materials (such as heat shrink tubing) may produce irritating fumes if overheat-

- ed. Always read and follow the appropriate material safety data sheets.
- 15. Certain circuit components affect the safe performance of equipment and systems. Use only exact or approved replacement parts.
- 16. Use protective clothing and safety glasses when handling high-vacuum devices such as picture tubes and cathode-ray tubes.
- 17. Don't work on equipment before you know proper procedures and are aware of any potential safety hazards.
- 18. Many accidents have been caused by people rushing and cutting corners. Take the time required to protect yourself and others. Running, horseplay, and practical jokes are strictly forbidden in shops and laboratories.

Circuits and equipment must be treated with respect. Learn how they work and the proper way of working on them. Always practice safety: your health and life depend on it.





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DATE		



Introduction

TEST: INTRODUCTORY CONCEPTS

NAME_

Choose the letter that best	completes each statement.	
1. The history of electron	nics is contained in a	1
a. 10-year period	c. 400-year period	
b. 100-year period	d. 800-year period	
2. The first person to ser	nd a radio signal across the Atlantic Ocean was	2
a. Marconi	c. Pickard	
b. DeForest	d. Benjamin Franklin	
3. The transistor was inv	ented by	3
a. Leonardo DaVinci		
b. Jack Kilby		
c. Scientists at Bell L	abs	
d. Tom Edison		
4. The integrated circuit	was invented	4
a. Before computers		
b. In 1958		
c. By engineers in Ge	rmany	
d. By Shockley	·	
5. An integrated circuit t	hat contains much of the circuitry of a computer is	5
a(n)		
a. Vacuum tube	c. Audion	
b. Crystal	d. Microprocessor	
6. A circuit that processe	s signals at an infinite number of voltage levels is	6
a. Defective	c. Digital	
b. Analog	d. DSP	
7. The waveforms in dig	tal circuits are	7
a. Rectangular	c. Sinusoidal	
b. Parabolic	d. None of the above	
8. The name for a circuit	that converts music into binary numbers is	8
a. Compressor		
b. D/A converter		
c. A/D converter		
d. All of the above		
Questions 9 to 11 refer to	Fig. 1-1.	
9. The analog function(s)	is (are)	9
a. A		
b. B		
c. C		

d. A and C

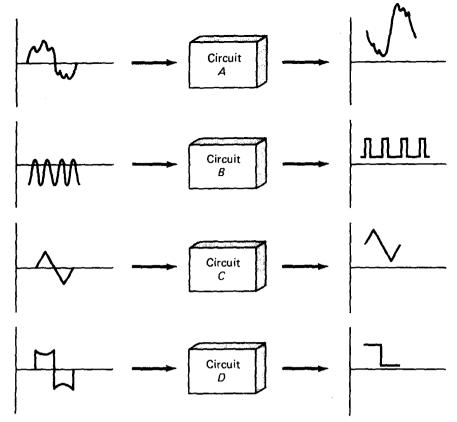


Fig. 1-1 Digital and analog circuits for Questions 9 through 11.

10. The digital function	n(s) is (are)	10
a. A	c. C	
b. B and D	d. All of the above	
11. The circuit output(s) with a dc component is (are)	11
a. A	c. C	
b. B and D	d. All of the above	
12. The number of volt	age levels available from a 7-bit D/A converter is	12
a. Infinite	c. 128	
b. 256	d. 64	
13. Making a signal lou	ider, larger, or stronger is called	13
a. Oscillation	·	
b. Attenuation		
c. Regulation		
d. Amplification		
14. Circuits that remove	e unwanted noise or unwanted frequencies are	14
a. Filters	•	
b. Detectors		
c. Multipliers		
d. Rectifiers		
15. Illustrations that sho	ow individual parts and how they are wired are called	15
a. Waveforms		
b. Block diagrams		
c. Schematic diagra	ms	
d. Voltage charts		
16. Illustrations that sho	ow the function of each major section are called	16
a. Timing diagrams	-	
b. Block diagrams		
c. Schematic diagra	ms	
1 41.		

d. Alignment charts

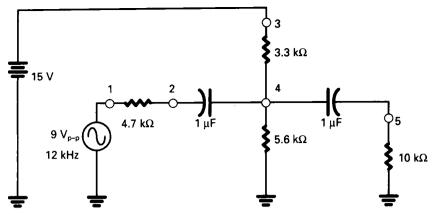


Fig. 1-2 Circuit for Questions 17 through 25.

Questions 17 to 25 refer to Fig. 1-2.

17.	The dc voltage at node 1 is		17
	a. 0	c. 2.42	
	b. 1.72	d. 15	
18.	The ac peak-to-peak voltage a	t node 2 is	18
	a. 0	c. 2.41	
	b. 1.72	d. 9	
19.	The ac peak-to-peak voltage a	t node 3 is	19
	a. 0	c. 2.41	
	b. 1.72	d. 15	
20.	The ac peak-to-peak voltage a	t node 4 is	20
	a. 0	c. 2.41	
	b. 1.72	d. 9	
21.	The dc voltage at node 4 is		21
	a. 0	c. 9.44	
	b. 7.5	d. 15	
22.	The dc voltage at node 5 is		22
	a. 0	c. 9.44	
	b. 2.41	d. 15	
23.	The ac peak-to-peak voltage at	t node 5 is	23
	a. 0	c. 9	
	b. 2.41	d. 9.44	
24.	If the 10 -k Ω resistor is replaced	d with a short, the ac voltage at node 4 will	24
	a. Increase to 15 V _{p-p}	c. Drop to 2.41 V_{p-p}	
	b. Not change	d. Drop to near zero	
25.	If the $10-k\Omega$ resistor is replace	ed with a short, the dc voltage at node 4	25
	will		
	a. Increase to 15 V	c. Drop to 2.41 V	
	b. Not change	d. Drop to near zero	
26.	Printed circuit boards may be	built using insertion technology or	26
	a. Plated-through holes	c. Ribbon cables	
	b. Multiple layers	d. SMT	
27.	Experience in making any part	cicular integrated circuit	27
	a. Decreases cost		

b. Increases yieldc. Increases reliabilityd. All of the above

1-1 LAB EXPERIMENT: AC/DC CIRCUIT

PURPOSE

To analyze the waveforms for a circuit with both ac and dc components.

MATERIALS

Qty.

- 1 oscilloscope
- 1 0- to 20-V dc power supply
- 1 audio signal generator
- 3 10-k Ω resistors
- 1 3.3-k Ω resistor
- 2 $0.1-\mu F$ capacitors
- 1 25-μF 15-V electrolytic capacitor

INTRODUCTION

Capacitors are used for signal coupling, dc blocking, and ac bypassing. The waveforms found in electronic circuits can be pure alternating current, pure direct current, or a combination of alternating and direct current. This experiment will give you an opportunity to gain experience with circuits having both ac and dc waveforms. It will also allow an investigation of some of the ways capacitors can be used.

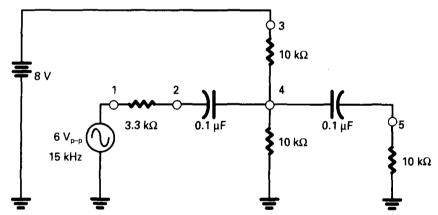


Fig. 1-3 AC/DC circuit.

PROCEDURE

- 1. Build the circuit shown in Fig. 1-3.
- 2. Set the dc power supply for 8 V.
- 3. Set the signal generator for sine wave output at a frequency of 15 kHz. Adjust the generator amplitude to $6 V_{p-p}$.
- Set the oscilloscope vertical sensitivity to 2 V/DIV and the horizontal time base to 20 μs/DIV.
- 5. The vertical input of the oscilloscope must be set for dc coupling.
- **6.** Ground the input probe of the oscilloscope.
- 7. Set the oscilloscope to Automatic Triggering. Carefully adjust the Vertical Position control so that the trace is exactly in the center of the screen.
- 8. Adjust the Brightness and Focus for a sharp trace.
- 9. Connect the oscilloscope ground to your circuit ground.

Note: If at any time during the following steps the oscilloscope display is not locked, adjust the Trigger Level control for a stable screen waveform.

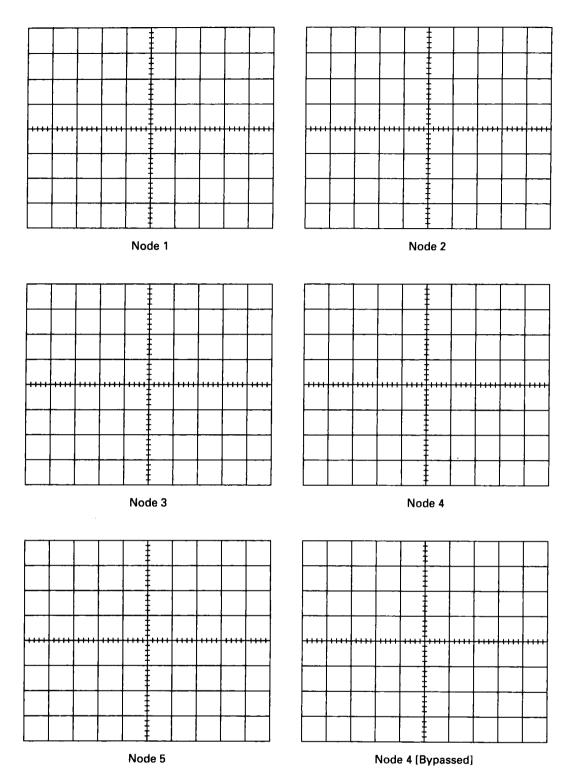


Fig. 1-4 Oscillographs for Experiment 1-1.

- **10.** Probe Node 1 of the circuit (refer to Fig. 1-3). Record the waveform for Node 1 on Fig. 1-4.
- 11. Probe Node 2 of the circuit. Record the waveform for Node 2 on Fig. 1-4.
- 12. Probe Node 3 of the circuit. If the waveform is off the screen, slowly reduce the output of the dc power supply to move the waveform onto the display area. Record the waveform for Node 3 on Fig. 1-4.
- 13. Probe Node 4 of the circuit. Record the waveform for Node 4 on Fig. 1-4
- **14.** Probe Node 5 of the circuit. Record the waveform for Node 5 on Fig. 1-4.

- 15. Modify the circuit as shown in Fig. 1-5. Observe the *polarity* of the $25-\mu F$ electrolytic bypass capacitor.
- **16.** Probe Node 4 of the modified circuit. Record the waveform for Node 4 [Bypassed] on Fig. 1-4.

DISCUSSION TOPICS

- 1. Where is the 0 V dc reference on the oscilloscope screen as set for this experiment? Why?
- 2. Could the oscilloscope 0 V dc reference be changed? How?
- 3. What are the $0.1-\mu F$ capacitors often called as they are used in Fig. 1-3?
- 4. What is the $25-\mu F$ capacitor called as it is used in Fig. 1-5? Why?
- 5. What would happen to the signal amplitude at Node 5 in Fig. 1-3 if the ac signal generator was adjusted to a much lower frequency? Why?
- 6. What would happen to the signal amplitude at Node 5 in Fig. 1-3 if the ac signal generator was adjusted to a much higher frequency? Why?

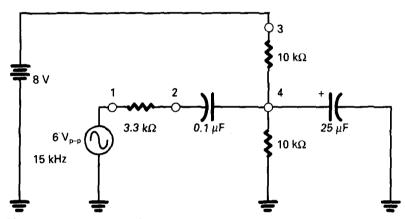


Fig. 1-5 Bypassing Node 4.

1-2 LAB EXPERIMENT: AC CIRCUIT REVIEW

PURPOSES

- 1. To review basic ac circuit concepts of impedance, filter action, and resonance
- 2. To experience an open-ended lab assignment.

MATERIALS

Qty.

- 1 oscilloscope
- 1 audio signal generator
- 1 220- Ω resistor
- 1 $0.5-\mu F$ capacitor
- 1 30-mH coil
- 1 circuit simulation package, including computer and software (optional)

INTRODUCTION

Simplified models are used often by engineers and technicians. In many cases, it is not necessary to do a detailed analysis for a given circuit's impedance, phase angle, voltage drops, currents, and power dissipation. An overview of how a given circuit will behave, in general terms, over a range of frequencies is extremely valuable when troubleshooting and/or doing system analysis.

PROCEDURE

This is an open-ended lab. Your instructor will assign some or all of the circuits shown in Fig. 1-6. These circuits can be built in the lab and analyzed using test equipment, and/or they can be simulated on a computer. Again, your instructor will inform you as to how you are to proceed. Your lab report might include data taken in the lab, and data taken from simulations, calculations, and other material.

You might not be comfortable with open-ended labs, but on-the-job tasks for electronics technicians are often open-ended. It is up to the technician to solve a problem or complete a task using the resources on hand.

Your instructor might give you additional hints and suggestions, but here are some items to consider:

- 1. Each circuit in Fig. 1-6 shows a voltage source in series with a 50- Ω resistor labeled $R_{\rm in}$. You should not use an actual resistor when building the circuit; this is the output impedance of a typical audio signal generator or function generator that you use in the lab. If you use a computer simulator, you will need this resistor in series with an ideal voltage source. An ideal voltage source has 0 Ω of series impedance.
- 2. You should use basic circuit theory to verify what happens in each assigned circuit. Some useful tools include Ohm's law, Kirchhoff's laws, capacitive reactance, inductive reactance, the voltage divider equation, and the resonant frequency equation (for a given value of L and C).
- 3. Some useful symbol definitions include: >> (much greater than), \approx (approximately equal to), and << (much less than).
- 4. The terms "low frequency" and "high frequency" are relative ones. So, how should you interpret them for Fig. 1-6? Generally, one can find starting points by using the reactance equations and solving for the frequencies that produce reactances 10 times and one-tenth of the value of the load. In Fig.