

EXPERIMENTS IN

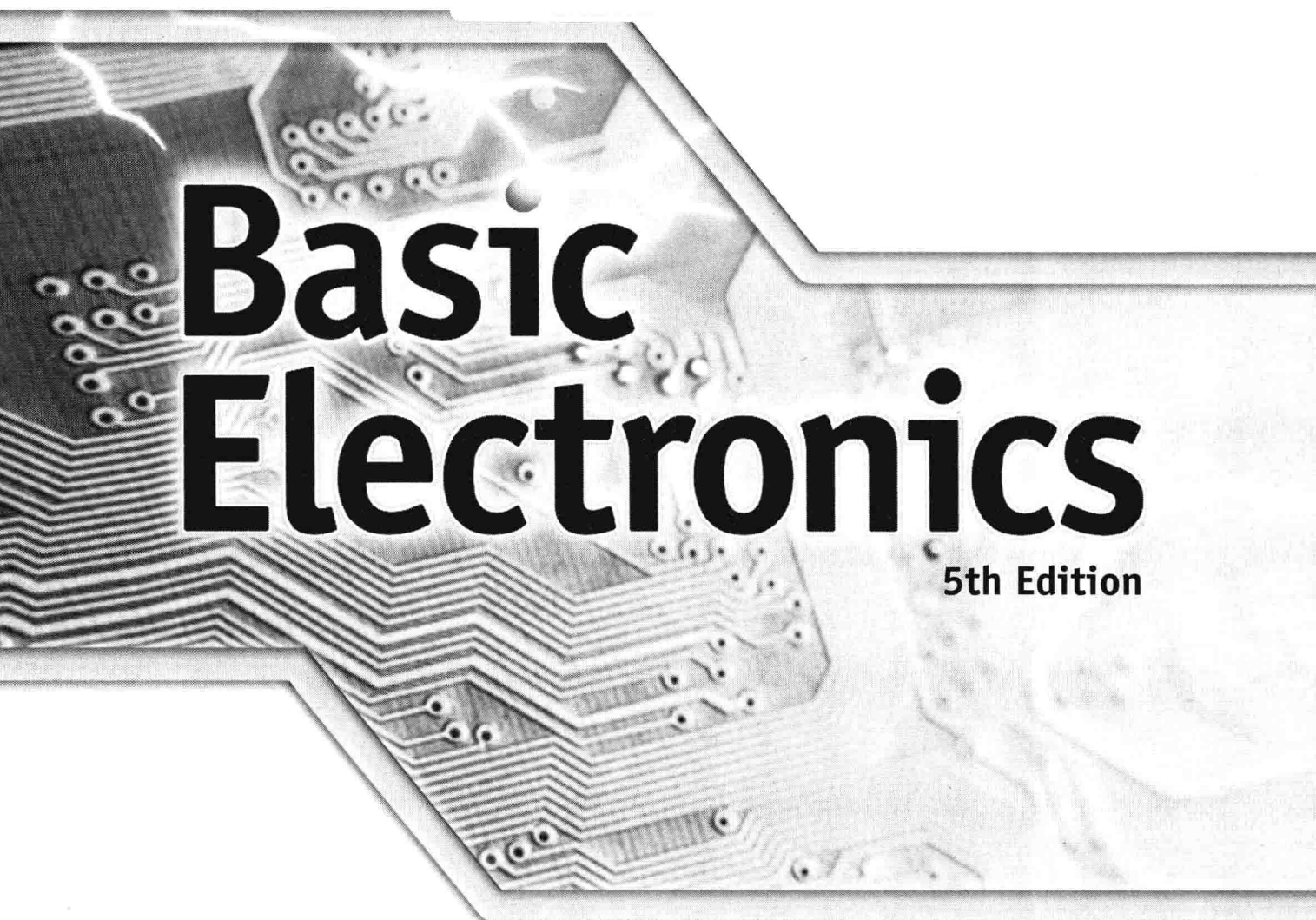
Basic Electronics

5th Edition

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EXPERIMENTS IN



Basic Electronics

5th Edition

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New York, New York Columbus, Ohio Chicago, Illinois Peoria, Illinois Woodland Hills, California

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Experiments in Grob Basic Electronics, Fifth Edition

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Send all inquiries to:
Glencoe/McGraw-Hill
8787 Orion Place
Columbus, OH 43240

ISBN 0-07-827125-8

1 2 3 4 5 6 7 8 9 071 07 06 05 04 03 02

Preface

Experiments in Basic Electronics is a lab manual for the beginning electronics student who does not have any previous experience in electricity or electronics. It has been developed especially for use with *Basic Electronics*, Ninth Edition, by Bernard Grob and Mitchel Schultz. The experiments are coordinated with the text chapter-by-chapter. In total, there are over 70 experiments, starting with basic safety, lab equipment, and identification of electronic components. All basic aspects of circuit theory are covered, ranging from Ohm's law through series-parallel circuits, reactance and circuits with active devices such as diodes and transistors. The emphasis throughout is on basic concepts and validation of theory through collecting data and reporting the results. Although the experiments build on one another, with simple concepts being developed before more complex subjects are introduced, minor modifications in the sequence can be made as necessary to suit the requirements of an individual electronics program. All experiments have been student-tested to ensure they can be followed with little or no assistance in the laboratory classroom.

Five experiments have been added for this edition to make the coverage of this manual more comprehensive. These additions are the result of instructor responses to a questionnaire distributed before work on the revision was begun. We thank all the instructors who provided us with opinions and suggestions for this edition.

Also in this edition, the order in which the experiments appear has been changed so that they directly correlate with the Grob text, chapter-by-chapter, and all of the chapters in the text are represented by at

least one experiment. For the convenience of students and instructors alike, report sheets are supplied for each experiment, where appropriate.

Each experiment, which takes approximately two to three hours to perform, is organized as follows. First, the basic principles are explained in detail; then, the student is encouraged to apply electronics theory to troubleshooting; and finally, the student writes a comprehensive report. Techniques for good technical report preparation are discussed in the first group of experiments. Additional information and blank graph paper for preparing reports is provided in Appendixes D and E.

A CD is included as a bonus with this edition. This disk contains the Multisim textbook edition program and 40 simulation activities. These simulation activities provide students with extra experience using the prelabs, and with additional exercises including critical thinking and troubleshooting practice related to select hands-on experiments. The prelabs are intended to help students to better prepare for their hands-on experience. The Critical Thinking and Troubleshooting labs are designed to challenge students by applying their knowledge to a variety of situations.

The authors would like to thank the instructors and students at Santa Rosa Junior College, Electronics Department, for their support and assistance throughout the years. We also wish to thank all the instructors at technical schools throughout the U.S.A. and the world who continue to offer suggestions and improvements. And finally, we thank our family and friends for their patience and support.

*Frank Pugh
Wes Ponick*

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LAB SAFETY, EQUIPMENT, AND COMPONENTS

OBJECTIVES

At the completion of this experiment, you will:

- Know the basic safety concepts used in a lab.
- Be familiar with lab equipment and components.
- Know the resistor color code.

SUGGESTED READING

Chapters 1 and 2, *Basic Electronics*, Grob/Schultz, Ninth Edition

INTRODUCTION

An electronics lab combines a classroom with a technician's workbench. Most classroom labs have similar equipment. You should become familiar with the equipment in your classroom lab, including safety equipment, safety policies, and practices.

SAFETY

Safety always comes first—in a lab class and at work. In fact, most large companies train their technicians in safety measures, including good ergonomic practices. You should not only know how to use the equipment safely but also how to sit at a lab station without stressing your arms, wrists, or eyes when working. Most of the time, this is a matter of common sense—avoid any stressful position for a prolonged time.

But most safety issues in an electronics lab come from the possibility of getting an electric shock. It is your responsibility to avoid this hazard by following these basic rules:

1. Do not plug in or turn on the power to any equipment without knowing how to use the equipment. This means asking for help when you do not know how to use something safely. Do not be afraid to ask for help.
2. Always check power cords. They should not be frayed, loose, or damaged in any way. In general, always inspect your equipment before using it.
3. Never wear loose jewelry or rings when working on equipment. Most jewelry is made

of metal and may conduct hazardous current accidentally.

4. Do not keep drinks or open liquids near electronic equipment.
5. Do not touch any circuit or components unless you know that it is safe to do so. For example, touching some components (especially some chips) can damage them. Other components (large capacitors) can discharge a dangerous current through your body if you touch them—even if they are not connected to a circuit.
6. Never use a soldering iron without proper training.
7. Never disturb another person who is using equipment.
8. Always wear safety glasses or any other required safety equipment.

Your lab class may have a safety test, signs, or some other information that you should read or respond to as required. Although most electronics courses are not known to cause injury, it is still a good idea to be cautious and prepared. Be sure you know where first aid is available and what to do in an emergency.

EQUIPMENT

Every electronics lab, and every school, has different types of equipment. However, there are some basic meters that are common to all electronics labs. In one form or another, your school will have these meters. They may appear to be different only because they are made by different manufacturers. Typical equipment is shown in Grob's *Basic Electronics*.

Simple Meters (Single Purpose)

Ohmmeter: Used to measure resistance (in ohms). Remember that resistance is the opposition to current flow in a circuit. Resistors usually have color stripes on them to identify their values. One way to be sure your resistor is the correct value is to measure it with an ohmmeter.

Ammeter: Used to measure current (in amperes). Remember that current is an electric charge in motion.

Ammeters usually measure the current in milliamperes (0.001 A), because most electronics lab courses do not require large amounts of current.

Voltmeter: Used to measure voltage (in volts). Remember that voltage (force) refers to units of potential difference. Most voltmeters use more than one range, or scale, because voltage, unlike current, is often measured in larger values.

Multimeters (Multipurpose)

VOM (VOLT-OHM-MILLIAMMETER): A multipurpose meter used to measure dc and ac voltage, dc current, and resistance (see Fig. 1-1.1a).

VTVM (VACUUM TUBE VOLTMETER): Another, older type of multipurpose meter used to measure voltage and resistance only.

DMM (DIGITAL MULTIMETER): A digital multipurpose meter, also known as a DVM (digital voltmeter) (see Fig. 1-1.1b).

Other Equipment

DC Power Supply: A source of potential difference, like a battery. It supplies voltage and current, and it can be adjusted to provide the required voltage for any experiment.

Soldering Iron: A pointed electric appliance that heats electric connections so that solder (tin and

lead) will melt on those connections. Used to join components and circuits.

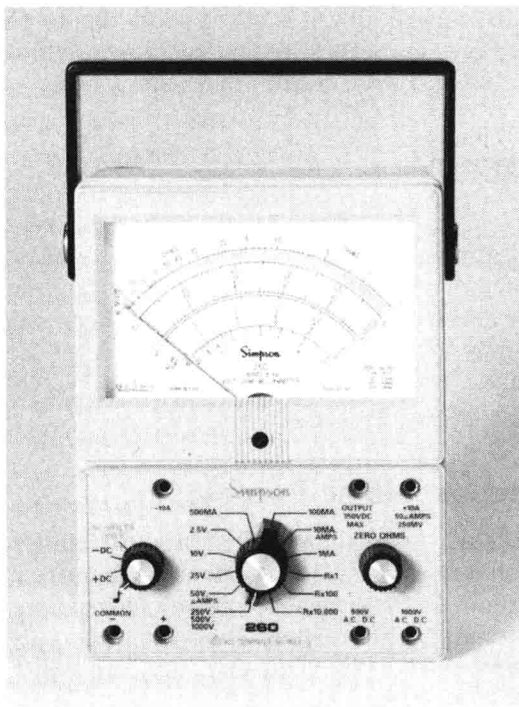
Breadboard/Springboard/Proto-board: Used to assemble basic circuits, by either soldering, inserting into springs, or joining together in sockets. These boards are the tools of designers, students, and hobbyists.

Component Familiarization (Symbols)

- — The symbol for resistance or a resistor.
- — The symbol for a battery (cells) or a power supply.
- + Positive symbol (associated with the color red).
- − Negative symbol (associated with the color black).
- — Capacitor (or capacitance) symbol. Used in later study.
- — Inductor (or inductance) symbol. Used in later study.

Leads are simply insulated wires used to join the meters to the circuits, the power supply to the circuit, etc. They are conductors and have no polarity of their own. Leads have different types of connectors on the ends, such as alligator clips, banana plugs, and BNC connectors.

Ω = ohms (unit of resistance), Greek letter omega
 ∞ = infinity (used to indicate infinite resistance)



(a)



(b)

Fig. 1-1.1 Basic meters. (a) VOM. (b) DMM.

Common Symbols for Multipliers

Lowercase k = kilo = 1000 or 1×10^3

Uppercase M = mega = 1,000,000 or 1×10^6

Lowercase m = milli = 0.001 or 1×10^{-3}

Greek letter mu (μ) = micro = 0.000 001 or 1×10^{-6}

COMPONENTS

Certain basic components are used in electronics all the time. They are the resistor, the capacitor, the inductor (see Fig. 1-1.2), the diode, and the transistor. Along with these are also hundreds of variations and customized devices and chips.

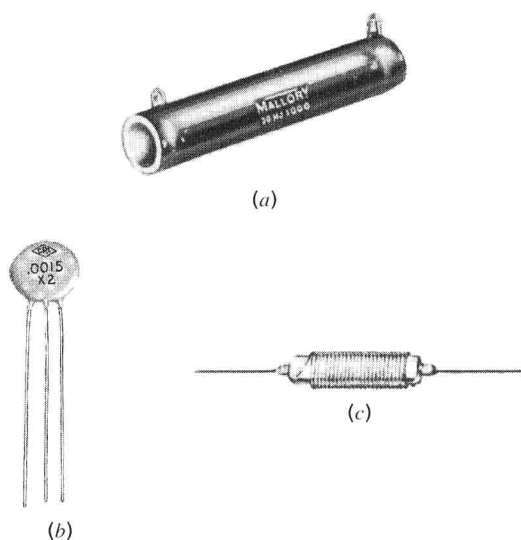


Fig. 1-1.2 Typical resistor (a), capacitor (b), and inductor (c).

Capacitors have the ability (capacity) to store electrical energy, and inductors have the ability to induce a voltage; these will be studied later. But the practical use of resistors is studied early in most lab classes. Learning about resistors and learning (memorizing) the resistor color code are critical for any technician.

In general, resistors limit or resist the flow of current in a circuit. That is why they are called *resistors*. Made of a carbon compound, resistors come in various sizes and power ratings. The most common resistors on circuit boards have the value of resistance color-coded (painted) on them. The value of resistance is the *ohm*, named for Georg Simon Ohm, the scientist who determined a law for resistance in 1828. The resistance value in ohms refers to the resistor's ability to resist the flow of electricity. The lower the

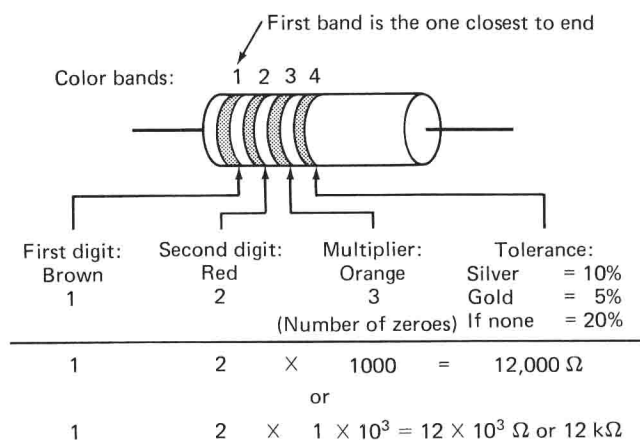
value, the less resistance. In practical applications, one ohm (1Ω) of resistance is very small and has little effect on most circuits. However, 1 million Ω has so much resistance that it resists all but the smallest amount of current flow.

PROCEDURE

Resistor Color Code

1. Answer questions 1 to 15.
2. After studying the resistor color code in Fig. 1-1.3, fill in Tables 1-1.1 and 1-1.2.
3. List the types of meters that you already know how to use and compare them to any meters in your lab.

After you finish, turn in your answers to procedure steps 1, 2, and 3.



Remember: Multiplier means adding zeros.
Here, add three zeros.

Note: If the multiplier (third band) is gold, multiply by 0.1.
Here, a gold band multiplier would mean 1.2 Ω . If the multiplier is black, multiply by 1.

COLOR CODE

Color	Value	Color	Value
Black	0	Green	5
Brown	1	Blue	6
Red	2	Violet	7
Orange	3	Grey	8
Yellow	4	White	9

Fig. 1-1.3 How to read color bands (stripes) on carbon resistors. Resistors come in various shapes and sizes. This is only one common form. The larger the physical size, the greater the wattage rating. Refer to Appendix C for other component codes, including the five-band carbon film resistors.

RESULTS FOR EXPERIMENT 1-1

QUESTIONS

Fill in the blanks (1–15) with the letter of the correct answer.

- | | |
|--|---|
| _____ 1. An instrument used to measure potential difference. | a. ammeter |
| _____ 2. An instrument used to measure current. | b.  |
| _____ 3. An instrument used to measure resistance. | c. power supply |
| _____ 4. A passive component that opposes the flow of current. | d. voltmeter |
| _____ 5. An instrument used to heat solder and join components. | e.  |
| _____ 6. A source of dc voltage other than a battery. | f. black |
| _____ 7. A symbol for dc voltage source. | g. ohmmeter |
| _____ 8. A symbol for resistance. | h. breadboard |
| _____ 9. A color used to represent negative polarity. | i. soldering iron |
| _____ 10. An item used to temporarily build circuits on. | j. resistor |
| _____ 11. A Greek letter used to represent a unit of resistance. | k. VOM/VTVM |
| _____ 12. An English letter used to represent 1000. | l. m |
| _____ 13. An English letter used to represent 0.001. | m. k |
| _____ 14. An instrument capable of measuring both voltage and current. | n. Ω |
| _____ 15. A symbol for infinity. | o. ∞ |

REPORT

TABLE 1-1.1 Resistor Color Codes

First Digit Band 1	Second Digit Band 2	Multiplier Band 3	Tolerance Band 4	Resistor Value
Red	Brown	Brown	Gold	_____
Brown	Brown	Black	Gold	_____
Green	Blue	Red	Silver	_____
Blue	Green	Yellow	Silver	_____
Red	Red	Orange	Silver	_____
Orange	White	Brown	Gold	_____
Blue	Green	Black	Silver	_____
Brown	Black	Red	Gold	_____
Yellow	Violet	Green	Gold	_____
Brown	Black	Orange	Silver	_____
Orange	Orange	Orange	Silver	_____
Brown	Black	Gold	Gold	_____
White	Blue	Red	Silver	_____
Brown	Black	Yellow	Silver	_____
Brown	Green	Green	Gold	_____

TABLE 1-1.2 Resistor Color Codes

Band 1 Color	Band 2 Color	Band 3 Color	Band 4 Color	Resistor Value
_____	_____	_____	_____	680 kΩ, 5%
_____	_____	_____	_____	10 kΩ, 10%
_____	_____	_____	_____	100 kΩ, 5%
_____	_____	_____	_____	3.3 MΩ, 5%
_____	_____	_____	_____	1.2 kΩ, 10%
_____	_____	_____	_____	820 Ω, 10%
_____	_____	_____	_____	47 kΩ, 5%
_____	_____	_____	_____	330 Ω, 10%
_____	_____	_____	_____	470 kΩ, 5%
_____	_____	_____	_____	560 Ω, 10%
_____	_____	_____	_____	1.5 MΩ, 10%
_____	_____	_____	_____	220 Ω, 5%
_____	_____	_____	_____	56 Ω, 10%
_____	_____	_____	_____	12 kΩ, 5%
_____	_____	_____	_____	560 kΩ, 5%

RESISTANCE MEASUREMENTS

OBJECTIVES

At the completion of this experiment, you will be able to:

- Read nonlinear meter scales.
- Calibrate and/or operate an ohmmeter.
- Measure resistance in ohms.

SUGGESTED READING

Chapters 1 and 2, *Basic Electronics*, Grob/Schultz, Ninth Edition

INTRODUCTION

This experiment will familiarize you with resistance measurements and the ohmmeter. Ohmmeters measure resistance in *ohms*, which is the opposition to current flow in a circuit. An ohmmeter works by sending a known value of current through a component and measuring the amount of current that returns. The difference is then used to determine the resistance. For example, if all the current sent is returned, the ohmmeter reading will be zero ohms ($0\ \Omega$) or no resistance. Or, if no current returns, the reading will be very large (millions of ohms) or infinity. Anything in between is determined by the internal circuitry and the applied voltage.

An ohmmeter can measure amounts of resistance from zero ohms, such as a short piece of copper wire (a *short circuit*) to infinite ohms, such as air (an *open circuit*). But, most of the time, you will use the ohmmeter to measure the value of resistors in ohms.

Types of Ohmmeters

For practical purposes, no single piece of equipment is dedicated to measuring ohms. Some older labs (schools) may use dedicated ohmmeters, but they are inadequate for use in the field and not found in modern test and production facilities. In general, ohmmeters are a functional part of multipurpose meters, which often also measure voltage and current. In fact, the only single-function ohmmeter that is practical is a continuity checker, which is used simply to verify that a circuit is closed (continuous) or open (no continuity).

Both digital and analog meters are used, with the digital meter currently the meter of choice. Analog meters use a meter movement and have nonlinear scales which are used only for resistance measurements—this is because the concept of infinite ohms cannot be fit onto a readable scale. In addition, all multifunction meters require that you adjust the function switch for volts, amperes, or ohms, and you may also be required to adjust the range. With the range properly set, you simply multiply the scale reading by the range setting. Ohmmeters can be part of the following types of multipurpose meters.

VOM (volt-ohm-milliammeter): This multifunction meter measures voltage, current, or resistance. As an ohmmeter, it can be digital or analog. Most versions use a magnetic meter movement with a needle or pointer and a nonlinear scale for resistance measurements. Other scales appear on the meter for voltage and current. Many VOMs combine function and range switches. The VOM is usually battery operated and portable. It also can usually measure low values of current, and both dc and ac voltages. See Fig. 2-1.1.

VTVM (vacuum tube voltmeter): This multifunction meter is based on vacuum tube technology and requires ac power to operate the vacuum tube inside. VTVMs usually have separate switches for function and range. For years the VTVM was considered the best bench tool for technicians because it measured both ac and dc voltages. However, it cannot measure current and is rarely used in modern workplaces since it has been replaced by digital meters that perform the same tasks. Like the VOM, the VTVM must be calibrated before measuring resistance. It also can measure power (in watts). See Fig. 2-1.2.

EQUIPMENT

Ohmmeter: DMM, VOM, or VTVM

COMPONENTS

30 resistors, all 0.25 W unless indicated otherwise:

- | | |
|------------------|------------------------------------|
| (1) 10 Ω | (1) 4.7 k Ω |
| (1) 56 Ω | (1) 5.6 k Ω (0.5 W or less) |
| (1) 100 Ω | (3) 10 k Ω (0.5 W or less) |

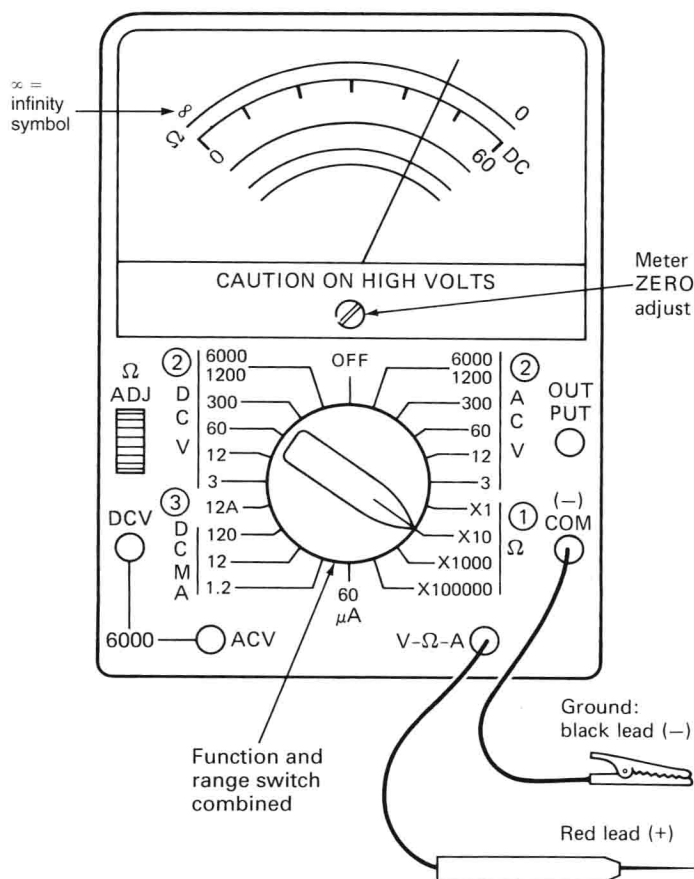


Fig. 2-1.1 VOM. Linear and nonlinear scale (ohms). A generic VOM measures resistance in ohms (Ω), ac and dc voltage, and current in amperes (A). The VOM shown is set for resistance: $R \times 10$.

(1) 220 Ω	(1) 22 k Ω (0.5 W or less)
(1) 390 Ω	(1) 33 k Ω (0.5 W or less)
(1) 470 Ω	(2) 47 k Ω (0.5 W or less)
(1) 680 Ω	(1) 68 k Ω (0.5 W or less)
(1) 820 Ω	(1) 86 k Ω (0.5 W or less)
(1) 1 k Ω	(2) 100 k Ω (0.5 W or less)
(1) 1.2 k Ω	(1) 220 k Ω (0.5 W or less)
(1) 1.5 k Ω	(1) 470 k Ω (0.5 W or less)
(1) 2.2 k Ω	(1) 1.2 M Ω (0.5 W or less)
(1) 3.3 k Ω	(1) 3.3 M Ω (0.5 W or less)

USING A VOM

Function/Range Switch: This rotary switch should be in the OFF position when not in use; otherwise, the VOM's battery may become depleted. Not only does this switch allow you to choose the desired functions (ohmmeter, voltmeter, ammeter), but it also indicates the range. VOMs often seem more difficult to use than VTVMs because they have so many switches and inputs located in a small area.

Ohms Adjust: This is the zero adjustment for measuring resistance (ohms). Use it to line up the nee-

dle directly on the zero line when using the VOM as an ohmmeter when the leads are shorted.

COM: This is the common or negative input. That is, it is the place where the black ground lead is plugged into the meter. Remember that VOMs, like most electronic instruments, have two inputs: a negative and a positive.

V Ω A: This is the positive input. Plug the other lead (red, if available) into this jack. Note that the words *jack*, *input*, *terminal*, and *plug-in* are often used interchangeably. You will become used to this terminology as you continue. This plug-in is used whenever measuring volts, ohms, or amperes (dc milliamperes).

Other Inputs: Do not be concerned with the other inputs at this time. You will not be using them. However, notice that the zero adjust is not marked on the VOM itself. This is because it is not adjusted (balanced) like the VTVM. If your VOM needle is not on the zero line in the dc volts function, adjust it here with a screwdriver.

Scales: The VOM has several scales. The nonlinear scale at the top is used for resistance measurements in ohms. The linear scale below is usually used for dc voltage. And the milliamperes scale (current measurements) may be another scale altogether, depending upon the manufacturer.

Function Switch: This switch turns the VTVM on. Actually, it is a rotary switch and should be in the OFF position when not in use. However, VTVMs require some warm-up time and are often left on during lab hours. The function switch allows you to choose the function you want from the VTVM. Thus, setting the function switch turns the VTVM into either an ohmmeter or a voltmeter (AC or +DC or -DC). You will probably use it as either an ohmmeter or a +dc voltmeter during your beginning studies. (See Fig. 2-1.2.)

Range Switch: This switch determines the scale that will be used. Notice that Fig. 2-1.2 shows eight different range settings. Each range setting corresponds to the function switch setting. For example, "15 V, $R \times 100$ " can be used for either a voltage or a resistance (ohms) measurement. In this case, if the function switch is on OHMS, the range would automatically be $R \times 100$, not 15 V.

Scales (Ohms and DC/RMS): The OHMS scale, marked Ω for resistance, is on top. It is a nonlinear scale (not equally divided). It goes from zero to infinity (∞). The scales below it are used for voltage and power measurements. DC and RMS are voltage measurements.

Zero Adjustment: This knob is a potentiometer that allows you to position the needle directly on the zero line before making a measurement.

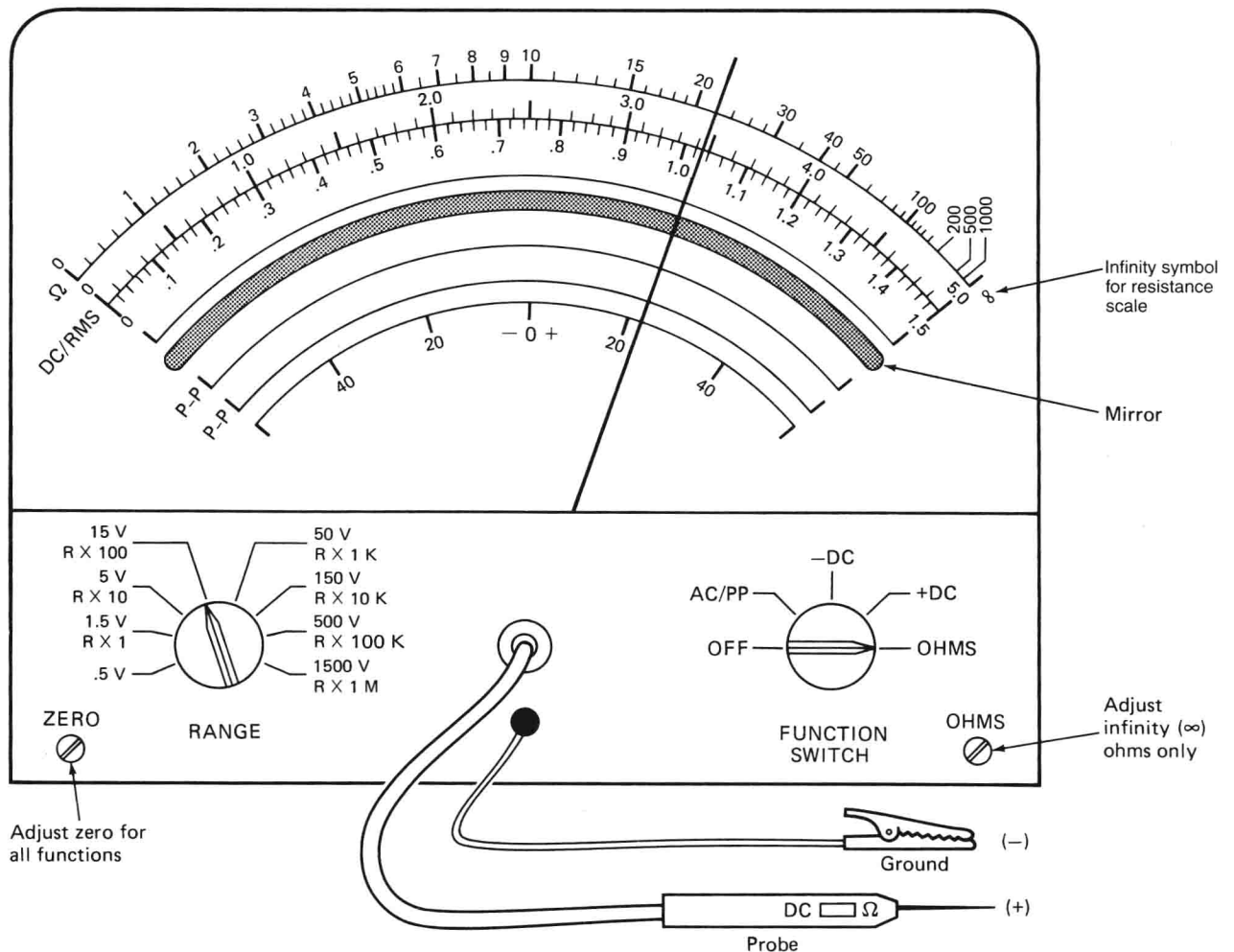


Fig. 2-1.2 VTVM (typical generic type). The top scale is nonlinear (0 to infinity), used for resistance (Ω). The remaining scales are linear (0 to 5, 0 to 1.5, etc.), used for voltage. Note that most VTVMs have a mirror strip between scales to prevent parallax errors. These visual errors are similar to those made by passengers in a car trying to read the speedometer from an angle. To avoid parallax errors, line up the needle with the mirror reflection, line up the needle with the division line on the scale.

Ohms Adjustment: This knob, also a potentiometer, allows you to line up the needle on the other end of the scale, on the infinity line. It is only used for resistance measurements (ohmmeter function).

Ground Lead: This lead is usually connected first. It is the negative ($-$), or ground, side. First, connect this ground strap or lead to one end of the component you are measuring. Then, make connection with the probe ($+$).

Probe: Often called the *positive lead*, this pointed probe has a switch on it for measuring either ohms or dc voltage. After the ground lead is connected, it is easy to use this probe to make contact with the component you are measuring.

DVM or DMM (digital voltmeter or digital multimeter): This is the most common type of multimeter for field use. It can measure resistance, voltage, and cur-

rent. It is usually small, portable (battery powered), and accurate. Of course, digital meters have an LED (light-emitting diode) display with the values displayed in digits. As with all meters, you must adjust the function and, sometimes, the range. The digital meter is the meter of choice for today's technician. See Fig. 2-1.3.

PROCEDURE

1. Reading Nonlinear Resistance Scales: Refer to Fig. 2-1.4. It shows the type of scales found on a VTVM. The top scale is nonlinear (uneven) and has an R label to indicate that it is used for resistance measurements only. The other scales below are used for voltage and power measurements. The scale goes from 0 (zero) to 1000, with infinity as the last increment or point on the scale. Notice also that the increment spacing is greater between



Fig. 2-1.3 DMM.

some numbers. This is due to the way the vacuum tube operates. For that reason, VTVM measurements are most accurate when the range is set so that the needle reading is near the center of the scale. There are 12 measurement readings in this figure. The first four readings have the values (answers in ohms) given where the range is shown multiplied by the needle position. Determine the best answers for readings 5 through 12, and be sure to record the values in Table 2-1.1 also.

2. Calibrate the Ohmmeter:

DMM: Digital Meter. Most handheld digital meters are easy to operate. First, become familiar with the meter and check with the instructor or the manual if you have any general questions. Digital meters normally require no calibration procedure. However, you should check to see whether the meter measures zero and infinite ohms correctly. Set the function to OHMS. With the leads shorted (connected), verify the reading of zero ohms. Next, disconnect the leads and verify infinite or many megohms. Try this in other ranges if applicable.

VTVM or VOM: Be sure that you are familiar with the meter operation as described in the previous sections. Refer to the manual for more information. When you are ready, use the following procedure to calibrate the meter so that it will give the correct resistance measurements.

Turn on the VTVM by setting the function switch to the OHMS position. Notice that the needle will go toward the infinity (∞) line. This is because infinite resistance is the starting point; between the ground lead and the positive lead (probe), there is only air, or infinite resistance.

Switch the probe to the OHMS position.

After allowing the VTVM to warm up for 1 or 2 min, connect both leads together, resulting in a short circuit, or zero resistance. The needle should now go in the other direction, toward zero.

Keeping both leads connected (short-circuited), use the ZERO adjust to align the needle (pointer) with the zero line. Be sure to use the mirror for proper alignment and reduction of parallax error. If the pointer, the zero line, and the mirror reflection are one, you have zeroed the ohmmeter correctly.

Disconnect the two leads. The needle will move toward the infinity line. Now, use the OHMS adjust and align the pointer with the infinity line. Alignment of the pointer, the infinity line, and the mirror reflection of the needle (pointer) will eliminate parallax errors.

Repeat the zero adjustment once more (short-circuit the leads together), and the meter should now be calibrated.

3. Resistor Measurements:

Set the range for $R \times 10$ if using a VOM/VTVM; DMM not required.

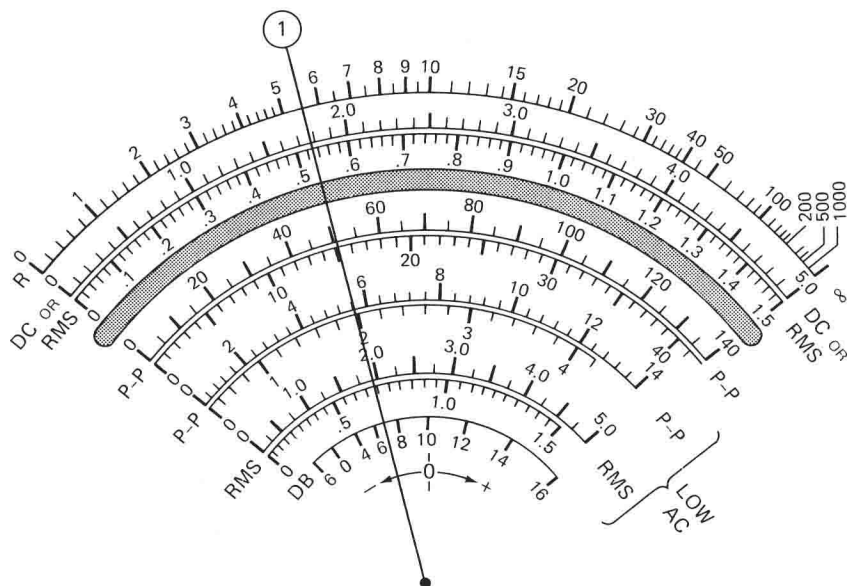
Connect the two leads across the 100- Ω resistor as shown in Fig. 2-1.5. It does not matter which side of the resistor you use; you may use either side. Also, never measure resistance when voltage is applied. You may damage the meter if you do.

Note: When measuring resistance, either end of the resistor can be connected. The resistor's polarity (+ or -) is due to the current passing through the resistor.

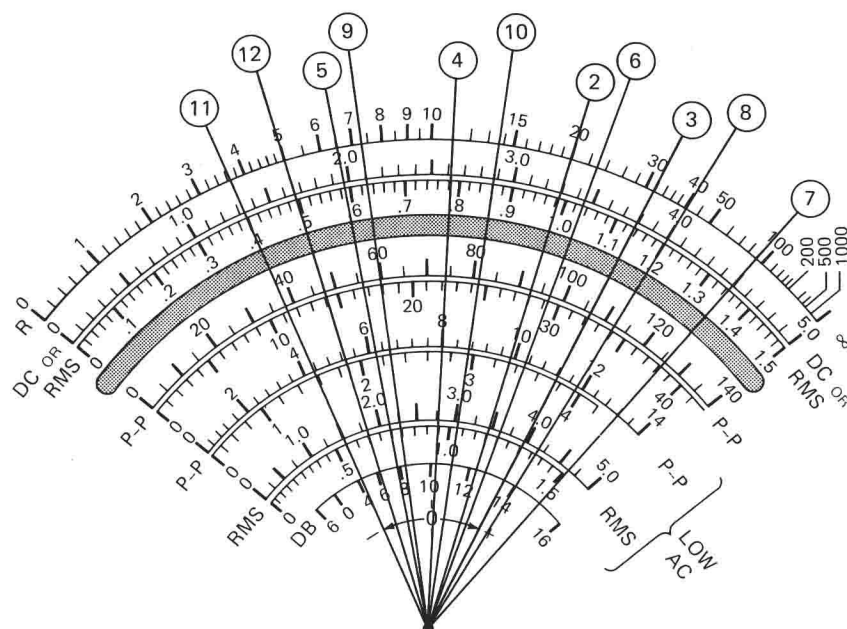
You should see the needle resting on or near the number 10 for DVM/VOM; DMM should read 100.

For VTVM/VOM: Multiply the number that the needle is indicating by the range setting. For example, if the needle is resting exactly between 9 and 10, at 9.5, multiply 9.5×10 . The 10 is for $R \times 10$. The result is 95 Ω . Do not be concerned if your measurement is not exactly 100 Ω . Remember that there may be differences due to manufacturing tolerances. Even a 100- Ω resistor with 10 percent tolerance (silver, fourth band) may be 90 Ω and still be good.

For all: Measure all the resistors listed in the component section. Write the measured value next to the nominal (color band) value in Table 2-1.2.



1. Range = $R \times 1 \text{ k}$
 Ans/Reading = 5.5 k Ω



- 2. Range = $R \times 100$ Ans = 2 k Ω
- 3. Range = $R \times 10$ Ans = 320 Ω
- 4. Range = $R \times 10$ Ans = 110 Ω
- 5. Range = $R \times 1 \text{ k}$ Ans = _____
- 6. Range = $R \times 100$ Ans = _____
- 7. Range = $R \times 10$ Ans = _____
- 8. Range = $R \times 1 \text{ k}$ Ans = _____
- 9. Range = $R \times 100$ Ans = _____
- 10. Range = $R \times 10 \text{ k}$ Ans = _____
- 11. Range = $R \times 1 \text{ M}$ Ans = _____
- 12. Range = $R \times 100 \text{ k}$ Ans = _____

Fig. 2-1.4 Ohmmeter and voltmeter scales (VTVM type). Record your answers to items 5 to 12 in Table 2-1.1.

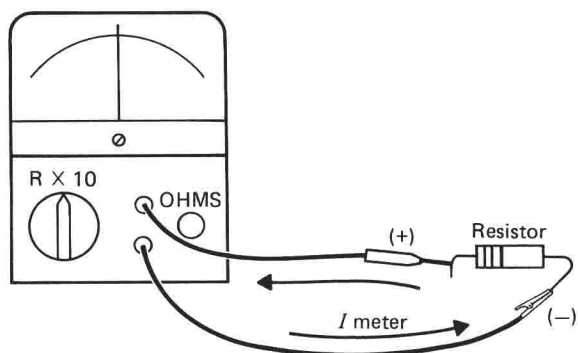


Fig. 2-1.5 Circuit building aid.

For VTVM/VOM: Always attempt to change ranges so that your measurements fall within the middle of the scale.

Readjust the OHMS (infinity) and ZERO controls each time you change ranges.

Remember that you cannot be entirely exact when reading scales. Do not be overly concerned if your values are not perfect.