Handbook of Electronic Circuits and Systems

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Preface

This text covers the principles of electronics from both the theoretical and the practical standpoints. It is intended to serve as a reference handbook of electronic fundamentals, applications, and systems. Early chapters are devoted to electrical and electronic technology, including the basic subjects of current flow, resistance, and electric power. In Chapter 1, tables are provided for Ohm's law, electronic symbols, and systems of units, including the international system of units (SI). Resistor and capacitor color codes are also provided for reference.

The measurement and analysis of resistance circuits are given in Chapter 2. Discussions include Kirchhoff's laws, Thevenin's and Norton's theorems, nodal and mesh calculations, and the decibel. Coils and capacitors are discussed in Chapter 3 and include time-constant data. Chapter 4 introduces alternating current, and the behavior of alternating current in circuits is covered in the next several chapters. Included are discussions on angular velocity, reactance, impedance, power factors, and combined *R, C,* and *L* circuitry. Resonance as it relates to selectivity in series and parallel circuits is covered in Chapter 7.

Coverage of solid-state and transistor principles begins in Chapter 8 and contains data on solid-state basics and diodes. Transistor circuitry and characteristics are covered in Chapter 9. Tables provide data on parameter symbols, as well as other miscellaneous symbols. Integrated circuitry is introduced in Chapter 10 and includes basic fabrication, symbols, and housings.

Electronic power supplies are covered in Chapter 11, and low-signal amplifiers are introduced in Chapter 12. Audio- and radio-frequency power amplifiers are discussed in Chapter 13, and as in all chapters, the topics are fully illustrated with appropriate schematic drawings. The oscillators used to generate electronic signals are described in Chapter 14. The principles of modulation and detection are covered in Chapter 15, with an emphasis on both amplitude and frequency modulation. Public-entertainment receiver principles are given in Chapter 16 and include AM and FM radios, television receivers, and bandpass factors. Listings are furnished on transmission characteristics and frequency allocations. The text concludes with Chapter 17 on digital circuits and systems. The fundamentals of logic circuitry are given including flip-flops, logic gates, and various logic-gate combinations.

Throughout the text, examples and cross-references have been included to aid the reader in gathering data in related areas.

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Electronic Units and Circuits

1-1. CURRENT, VOLTAGE, AND RESISTANCE

The unit of electric current is the *ampere,* named after André Ampere, the eighteenth-century French scientist. When a person's name is used to identify an electric or electronic term, it is not capitalized when spelled out. When an abbreviated letter symbol is used, however, it is capitalized. Thus, A is used to represent the *unit* ampere. The symbol I (italic) is used to represent the *quantity* current. Thus the expression $I = 2$A states that a current equals 2 amperes. One ampere of current is equal to the quantity of electrons flowing past a given point in 1 second (s) and represents 1 coulomb (C). A coulomb consists of 6.28×10^{18} electrons.

The electromotive force (*emf*) required to move electrons through a conductor develops an electric pressure designated as voltage. The unit volt is named after Alessandro Volta, an eighteenth-century Italian researcher. The letter E (italic) represents the quantity voltage, and the letter V represents the unit volt. Thus, the expression $E = 120$ V states that an electromotive force is equal to 120 volts (sometimes the word *potential* is also used for voltage). One volt is equal to the quantity of electromotive force that causes 1 A of current to flow through 1 ohm (Ω) of resistance.

Some materials conduct current more readily than others, and there are intermediate grades of conduction between zero and full conduction. The opposition within a material to electron flow is referred to as *resistance.* The symbol *R* (italic) represents the quantity resistance. The unit of resistance is the *ohm,* named after George Ohm, the German scientist who derived the mathematical equations known as *Ohm's law* (this is discussed in Sec. 1–3). The capital Greek letter *omega* (Ω) represents the unit ohm. Thus the expression $R = 50\ \Omega$ states that a resistance equals 50 ohms. One Ω is equal to the resistance of a column of mercury at 0°C having a dimension of 1 square millimeter (mm^2) of cross-sectional area with a length of 106.3 centimeters (cm).

The term *conductance* indicates the degree to which a substance permits current to flow. Conductance is the reciprocal of resistance and therefore equals $1/R$. Thus, if a resistance is 250 Ω, the reciprocal (conductance) is 1/250 (0.004). Originally the unit for conductance was the *mho* (ohm spelled backward); thus, in the foregoing example, the conductance is 0.004 mho. The letter S now represents the unit of conductance, *siemens.* The symbol *G* represents the quantity conductance. (See Sec. 1–8 and Table 1–4).

1–2. ELECTRIC POWER

Electric energy is used to operate motors, television receivers, fans, and many other devices. Such energy is usually referred to as electric power and has for its symbol *P.* The unit of electric power is the *watt* (W), named after the Scottish scientist James Watt. One watt of power equals 1 A of current with a potential of 1 V. Thus, $P = 30$ W indicates that an electric power consumed equals 30 watts.

Often, the amount of electric power consumed is related to elapsed time, and in such an instance the unit of energy is the *joule* (J). This unit is also called the *watt-second* and is equal to 1 W for 1 s.

1–3. OHM'S LAW

Table 1–1 lists the basic equations for Ohm's law.

TABLE 1-1. Summary of Ohm's Law Equations

$I =$	$\frac{E}{R}$	or	$\frac{P}{E}$	or	$\frac{P}{\sqrt{R}}$
$E =$	IR	or	$\frac{P}{I}$	or	$\sqrt{PR}$
$R =$	$\frac{E}{I}$	or	$\frac{P}{I^2}$	or	$\frac{E2}{P}$
$P =$	EI	or	I^2R	or	$\frac{E2}{R}$

Since the range of values used in electronics is great, the powers of 10 are often employed. These expressions (such as 10^3 for 10 to the third power) are referred to as *engineers' shorthand* or the *standard system of scientific notation.* Table 1–2 shows the notation with letter symbols in lowercase, except for mega, giga, and tera. Note that micro uses the Greek lowercase letter *mu* (μ).

TABLE 1-2. Quantities and Letter Symbols

Prefix	*Symbol*	*Value*	*Power*
tera	T	one million million	(1×10^{12})
giga	G	one thousand million	(1×10^{9})
mega	M	one million	(1×10^{6})
kilo	k	one thousand	(1×10^{3})
hecto	h	one hundred	(1×10^{2})
deca	da	ten	(1×10^{1})
deci	d	one-tenth	(1×10^{-1})
centi	c	one-hundredth	(1×10^{-2})
milli	m	one-thousandth	(1×10^{-3})
micro	μ	one-millionth	(1×10^{-6})
nano	n	one-thousandth of a millionth	(1×10^{-9})
pico	p	one-millionth of a millionth	(1×10^{-12})
femto	f		(1×10^{-15})
atto	a		(1×10^{-18})

Current values range from microamperes (μA), through milliamperes (mA), to amperes (A). Potential values range from microvolts (μV); through millivolts (mV), volts (V), kilovolts (kV); to megavolts (MV). Resistance values are not expressed as micro or milli values; fractional values are used for low resistance, such as 0.1 Ω, or 0.75 Ω. The common range for resistance values is from 1 Ω to over 1 million Ω. For thousands of ohms, the expression used is kilohm (kΩ), such as 2.5 kΩ for 2500 Ω. For 1 million ohms or more, the megohm (MΩ) is used, for instance, 3 MΩ. Power values range from microwatts (μW); through milliwatts (mW), watts (W), kilowatts (kW); to megawatts (MW).

1-4. BATTERIES AND RESISTORS

A *battery* consists of a number of *cells* connected together to supply a specific voltage and current. Flashlight batteries and electric watch batteries are actually cells having a voltage of 1.25 or 1.5, depending on the cell type. A single cell is illustrated in Fig. 1-1A; the positive and negative symbols indicate the polarity of each terminal. The symbol for a single cell is shown in Fig. 1-1B, although it also may be used to represent a battery. The structure of a basic battery is shown in Fig. 1-1C; it consists of four cells with the positive polarity terminal of each cell connected to the negative terminal of each other cell, as shown;

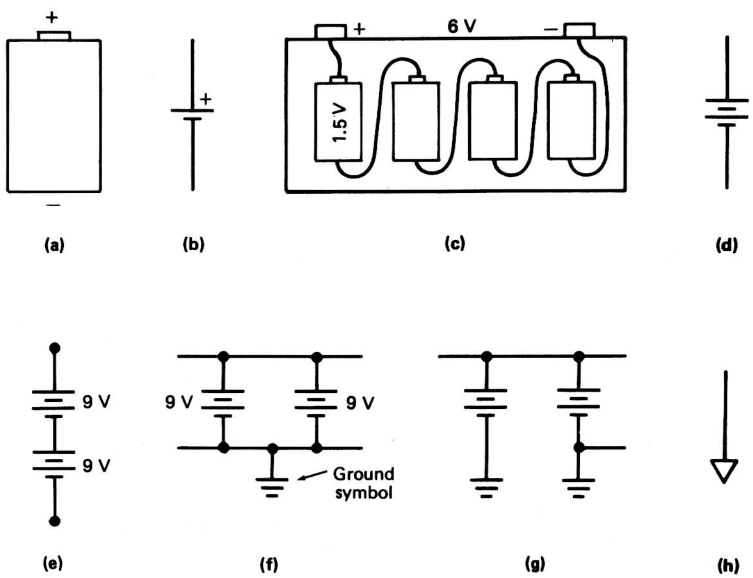

FIGURE 1-1. Cell and Battery Symbols.

therefore, the voltage of each cell adds together for a total voltage that is the sum of the individual voltages; thus, the battery supplies 6 V. For a 9-V battery, six cells would be required, each rated at 1.5 V. The symbol for a battery is shown in Fig. 1–1D. Although some polarities are shown in Fig. 1–1, they are not necessarily included in all drawings because as an industrial standard, the end of a battery or cell symbol with the short horizontal bar denotes negative polarity and the other end denotes positive polarity.

Figure 1–1E shows the representation for series-connected batteries with a total voltage available at the top and bottom terminals of 18 V. Figure 1–1F shows batteries connected in parallel. This arrangement does not increase voltage but can increase current. A battery is only capable of delivering a certain amount of current before it is overloaded. Thus, if a greater current output is desired, the parallel arrangement should be utilized.

Note the ground symbol in Fig. 1–1F. This symbol usually indicates a common electrical interconnection using the metal chassis or a strip of conductor instead of an actual connection to earth ground. For electrical distribution systems, however, the symbol indicates actual ground (such as a connection to a water pipe that runs through the ground or to a copper grounding rod). The ground symbol is commonly used in all circuit drawings. The circuit shown in Fig. 1–1F could be drawn as Fig. 1–1G and still represent the identical circuit. Since the ground symbol represents interconnections with the negative terminals of each battery, this same representation is present in Fig. 1–1G. Sometimes there are common linkages in a circuit that are not connected to a metal chassis or powerline ground. In such cases, the special ground symbol shown in Fig. 1–1H is used to designate a common linkage instead of the ground symbols shown in Figs. 1–1F and G.

A *resistor* is a device used to decrease potentials and currents as needed in an electronic circuit. Many resistor types are utilized in electronics; typical resistors are illustrated in Fig. 1–2. Figure 1–2A shows the composition carbon resistor that is widely used in all branches of electronics. (The colored bands indicate the ohmic value and the tolerance of the resistor.) Resistor color coding is discussed in Sec. 1–9. Resistors have various resistance values, ranging from resistors of fractional ohmic resistance to resistors of several megohms of resistance. For the composition carbon resistor, a wattage rating of more than 1 W is rarely used; most ratings

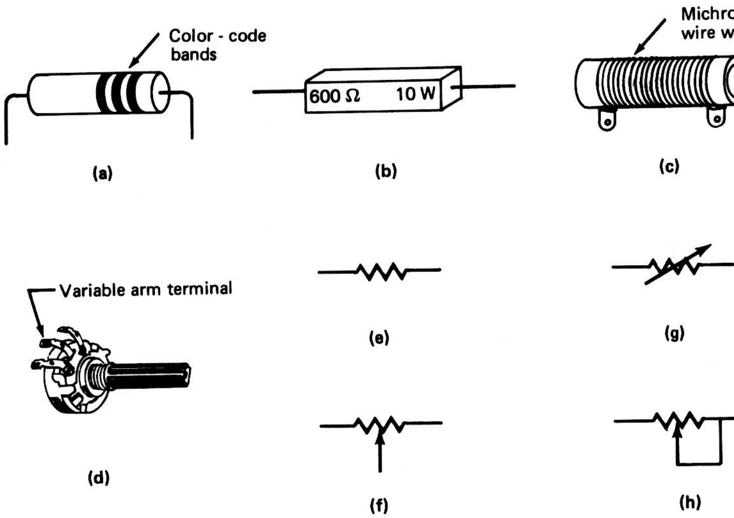

FIGURE 1–2. Resistors and Symbols.

are 1/4W and 1/2W. The Nichrome wire resistor has wattage ratings from a few watts to over 20 W. Resistors in the 5- to 10-W range are often encased in an oblong ceramic housing as shown in Fig. 1–2B; others (usually those above 15 W) consist of wire wound around a ceramic tubing with soldering lugs at each end, as shown in Fig. 1–2C.

The *variable resistor* is shown in Fig. 1–2D. A shaft is connected to a rotating wiper arm within a housing, and the wiper slides over a circular resistance strip. A center terminal is connected to the rotary arm section, and two terminals are connected to each side of a circular resistance strip. Variable resistors are used for tone controls, volume controls, and in many other applications, such as contrast and brilliance controls in televisions. For stereo systems, dual variable resistor housings are used with a common shaft that turns two separate electrically insulated variable wiper arms.

The symbol for the resistor is shown in Fig. 1–2E and consists of from three to eight zigzag sections. The variable resistor is indicated in Fig. 1–2F with an arrow representing the wiper arm. Variable resistors are also called *potentiometers* or *rheostats*, although the latter term usually refers to two-terminal variable resistors. The symbols shown in Figs. 1–2G and H are sometimes used for variable resistors.