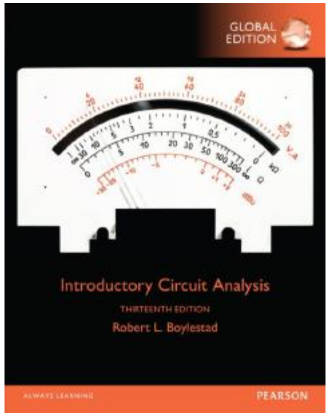
Introductory Circuit Analysis



CHAPTER 1

Introduction

OBJECTIVES

- Become aware of the rapid growth of the electrical/electronics industry over the past century.
- Understand the importance of applying a unit of measurement to a result or measurement and to ensuring that the numerical values substituted into an equation are consistent with the unit of measurement of the various quantities.

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OBJECTIVES

- Become familiar with the SI system of units used throughout the electrical/ electronics industry.
- Understand the importance of powers of ten and how to work with them in any numerical calculation.
- Be able to convert any quantity, in any system of units, to another system with confidence.

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THE ELECTRICAL/ELECTRONICS INDUSTRY

- Over the past few decades, technology has been changing at an ever-increasing rate.
- The reduction in size of electronic systems is due primarily to an important innovation introduced in 1958—the integrated circuit (IC).
- An integrated circuit can now contain features less than 50 nanometers across.

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THE ELECTRICAL/ELECTRONICS INDUSTRY

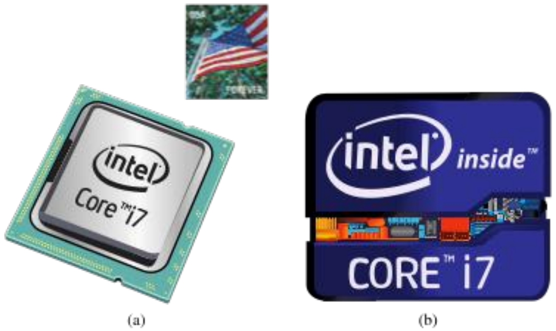

FIG. 1.1
Intel® Core™ i7 quad-core processor: (a) surface appearance, (b) internal chips.

A BRIEF HISTORY

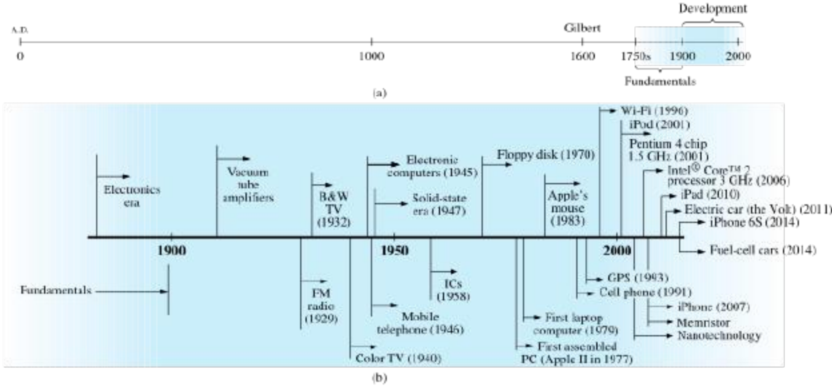

FIG. 1.2
Time charts: (a) long-range; (b) expanded.

A BRIEF HISTORY
The Beginning

- The phenomenon of static electricity has intrigued scholars throughout history.
  - The Greeks called the fossil resin substance so often used to demonstrate the effects of static electricity elektron, but no extensive study was made of the subject until William Gilbert researched the phenomenon in 1600.

A BRIEF HISTORY
The Beginning

- In the years to follow, there was a continuing investigation of electrostatic charge by many individuals, such as Otto von Guericke, who developed the first machine to generate large amounts of charge, and Stephen Gray, who was able to transmit electrical charge over long distances on silk threads.

A BRIEF HISTORY
The Beginning

- Charles DuFay demonstrated that charges either attract or repel each other, leading him to believe that there were two types of charge—a theory we subscribe to today with our defined positive and negative charges.
- There are many who believe that the true beginnings of the electrical era lie with the efforts of Pieter van Musschenbroek and Benjamin Franklin.

A BRIEF HISTORY
The Beginning

- In 1745, van Musschenbroek introduced the Leyden jar for the storage of electrical charge (the first capacitor) and demonstrated electrical shock (and therefore the power of this new form of energy).

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A BRIEF HISTORY
The Beginning

- Franklin used the Leyden jar some 7 years later to establish that lightning is simply an electrical discharge, and he expanded on a number of other important theories, including the definition of the two types of charge as positive and negative.

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A BRIEF HISTORY
The Beginning

- In 1784, Charles Coulomb demonstrated in Paris that the force between charges is inversely related to the square of the distance between the charges.
- In 1791, Luigi Galvani performed experiments on the effects of electricity on animal nerves and muscles.

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A BRIEF HISTORY
The Beginning

- The first voltaic cell, with its ability to produce electricity through the chemical action of a metal dissolving in an acid, was developed by another Italian, Alessandro Volta, in 1799.

A BRIEF HISTORY
The Beginning

- The fever pitch continued into the early 1800s, with Hans Christian Oersted, a Danish professor of physics, announcing in 1820 a relationship between magnetism and electricity that serves as the foundation for the theory of electromagnetism as we know it today.

A BRIEF HISTORY
The Beginning

- By the end of the 1800s, a significant number of the fundamental equations, laws, and relationships had been established, and various fields of study, including electricity, electronics, power generation and distribution, and communication systems, started to develop in earnest.

A BRIEF HISTORY
The Age of Electronics

- Radio
- Television
- Computers

A BRIEF HISTORY
The Solid-State Era

- In 1947, physicists William Shockley, John Bardeen, and Walter H. Brattain of Bell Telephone Laboratories demonstrated the point-contact transistor, an amplifier constructed entirely of solid-state materials with no requirement for a vacuum, glass envelope, or heater voltage for the filament.

A BRIEF HISTORY
The Solid-State Era

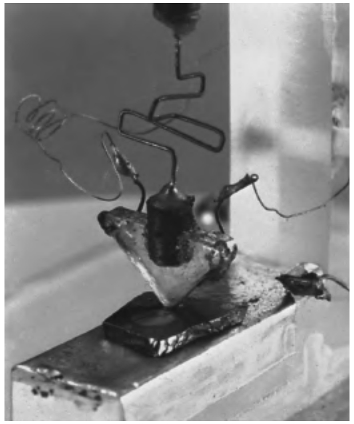

FIG. 1.3 *The first transistor.* (Reprinted with permission of Alcatel-Lucent USA Inc.)

A BRIEF HISTORY
The Solid-State Era

- Although reluctant at first due to the vast amount of material available on the design, analysis, and synthesis of tube networks, the industry eventually accepted this new technology as the wave of the future.

A BRIEF HISTORY
The Solid-State Era

- In 1958, the first integrated circuit (IC) was developed at Texas Instruments, and in 1961 the first commercial integrated circuit was manufactured by the Fairchild Corporation.

UNITS OF MEASUREMENT

- One of the most important rules to remember and apply when working in any field of technology is to use the correct units when substituting numbers into an equation.
- Too often we are so intent on obtaining a numerical solution that we overlook checking the units associated with the numbers being substituted into an equation.

UNITS OF MEASUREMENT

- Results obtained, therefore, are often meaningless.

SYSTEMS OF UNITS

- In the past, the systems of units most commonly used were the English and metric.
- Note that while the English system is based on a single standard, the metric is subdivided into two interrelated standards: the MKS and the CGS.

SYSTEMS OF UNITS

- The MKS and CGS systems draw their names from the units of measurement used with each system; the MKS system uses Meters, Kilograms, and Seconds, while the CGS system uses Centimeters, Grams, and Seconds.

SYSTEMS OF UNITS

TABLE 1.1
Comparison of the English and metric systems of units.

ENGLISH	METRIC		SI
	MKS	CGS	
Length: Yard (yd) (0.914 m)	Meter (m) (39.37 in.) (100 cm)	Centimeter (cm) (2.54 cm = 1 in.)	**Meter (m)**
Mass: **Slug** (14.6 kg)	Kilogram (kg) (1000 g)	Gram (g)	**Kilogram (kg)**
Force: **Pound** (lb) (4.45 N)	Newton (N) (100,000 dynes)	Dyne	**Newton (N)**
Temperature: Fahrenheit (°F) $\left(=\frac{9}{5}°C + 32\right)$	Celsius or Centigrade (°C) $\left(=\frac{5}{9}(°F - 32)\right)$	Centigrade (°C)	**Kelvin (K)** K = 273.15 + °C
Energy: Foot-pound (ft-lb) (1.356 joules)	Newton-meter (N•m) or joule (J) (0.7376 ft-lb)	Dyne-centimeter or erg (1 joule = 10^7 ergs)	**Joule (J)**
Time: Second (s)	Second (s)	Second (s)	**Second (s)**

SYSTEMS OF UNITS

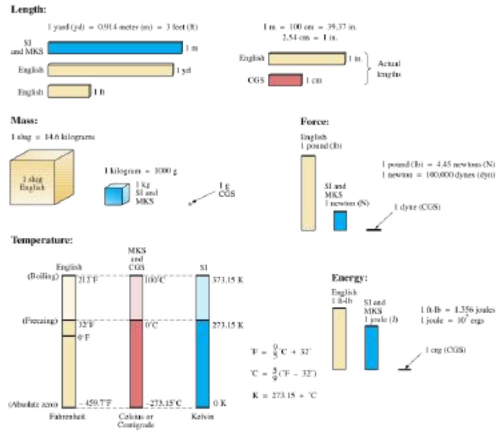

FIG. 1.4
Comparison of units of the various systems of units.

SIGNIFICANT FIGURES, ACCURACY, AND ROUNDING OFF

- Too often we write numbers in various forms with little concern for the format used, the number of digits that should be included, and the unit of measurement to be applied.
- In general, there are two types of numbers: exact and approximate.

SIGNIFICANT FIGURES, ACCURACY, AND ROUNDING OFF

- In the addition or subtraction of approximate numbers, the entry with the lowest level of accuracy determines the format of the solution.
- For the multiplication and division of approximate numbers, the result has the same number of significant figures as the number with the least number of significant figures.

POWERS OF TEN

- It should be apparent from the relative magnitude of the various units of measurement that very large and very small numbers are frequently encountered in the sciences.
- To ease the difficulty of mathematical operations with numbers of such varying size, powers of ten are usually employed.

POWERS OF TEN

- This notation takes full advantage of the mathematical properties of powers of ten.
- The notation used to represent numbers that are integer powers of ten is as follows:

$$10^0 \quad 1/10 = 0.1$$
$$10^1 \quad 1/100 = 0.01$$
$$10^2 \quad 1/1000 = 0.001$$
$$10^3 \quad 1/10{,}000 = 0.0001$$

POWERS OF TEN
Basic Arithmetic Operations

- Addition and Subtraction
- Multiplication
- Division

FIXED-POINT, FLOATING-POINT, SCIENTIFIC ENGINEERING NOTATION

- When you are using a computer or a calculator, numbers generally appear in one of four ways.
- If powers of ten are not employed, numbers are written in the fixed-point or floating-point notation.

FIXED-POINT, FLOATING-POINT, SCIENTIFIC ENGINEERING NOTATION

- The fixed-point format requires that the decimal point appear in the same place each time. In the floating-point format, the decimal point appears in a location defined by the number to be displayed.
- Scientific (also called standard) notation and engineering notation make use of powers of ten, with restrictions on the mantissa (multiplier) or scale factor (power of ten).

FIXED-POINT, FLOATING-POINT, SCIENTIFIC ENGINEERING NOTATION

- Engineering notation specifies that all powers of ten must be 0 or multiples of 3, and the mantissa must be greater than or equal to 1 but less than 1000.

FIXED-POINT, FLOATING-POINT, SCIENTIFIC ENGINEERING NOTATION

Multiplication Factors	SI Prefix	SI Symbol
$1\,000\,000\,000\,000\,000\,000 = 10^{18}$	exa	E
$1\,000\,000\,000\,000\,000 = 10^{15}$	peta	P
$1\,000\,000\,000\,000 = 10^{12}$	tera	T
$1\,000\,000\,000 = 10^{9}$	giga	G
$1\,000\,000 = 10^{6}$	mega	M
$1\,000 = 10^{3}$	kilo	k
$0.001 = 10^{-3}$	milli	m
$0.000\,001 = 10^{-6}$	micro	μ
$0.000\,000\,001 = 10^{-9}$	nano	n
$0.000\,000\,000\,001 = 10^{-12}$	pico	p
$0.000\,000\,000\,000\,001 = 10^{-15}$	femto	f
$0.000\,000\,000\,000\,000\,001 = 10^{-18}$	atto	a

TABLE 1.2

CONVERSION BETWEEN LEVELS OF POWERS OF TEN

- The procedure is best described by the following steps:
  - Replace the prefix by its corresponding power of ten.
  - Rewrite the expression, and set it equal to an unknown multiplier and the new power of ten.

CONVERSION BETWEEN LEVELS OF POWERS OF TEN

- Note the change in power of ten from the original to the new format. If it is an increase, move the decimal point of the original multiplier to the left (smaller value) by the same number. If it is a decrease, move the decimal point of the original multiplier to the right (larger value) by the same number.

CONVERSION WITHIN AND BETWEEN SYSTEMS OF UNITS

- The conversion within and between systems of units is a process that cannot be avoided in the study of any technical field.
- It is an operation, however, that is performed incorrectly so often that this section was included to provide one approach that, if applied properly, will lead to the correct result.

CONVERSION WITHIN AND BETWEEN SYSTEMS OF UNITS

- Let us now review the method:
  - Set up the conversion factor to form a numerical value of (1) with the unit of measurement to be removed from the original quantity in the denominator.
  - Perform the required mathematics to obtain the proper magnitude for the remaining unit of measurement.

SYMBOLS

TABLE 1.3

Symbol	Meaning
$\neq$	Not equal to $6.12 \neq 6.13$
$>$	Greater than $4.78 > 4.20$
$\gg$	Much greater than $840 \gg 16$
$<$	Less than $430 < 540$
$\ll$	Much less than $0.002 \ll 46$
$\geq$	Greater than or equal to $x \geq y$ is satisfied for $y = 3$ and $x > 3$ or $x = 3$
$\leq$	Less than or equal to $x \leq y$ is satisfied for $y = 3$ and $x < 3$ or $x = 3$
$\cong$	Appoximately equal to $3.14159 \cong 3.14$
Σ	Sum of $\Sigma(4 + 6 + 8) = 18$
$\|\ \|$	Absolute magnitude of $\|a\| = 4$, where $a = -4$ or $+4$
$\therefore$	Therefore $x = \sqrt{4} \therefore x = \pm 2$
$\equiv$	By definition Establishes a relationship between two or more quantities
$a{:}b$	Ratio defined by $\frac{a}{b}$
$a{:}b = c{:}d$	Proportion defined by $\frac{a}{b} = \frac{c}{d}$

CONVERSION TABLES

- Conversion tables such as those appearing in Appendix A can be very useful when time does not permit the application of methods described in this chapter.
- However, even though such tables appear easy to use, frequent errors occur because the operations appearing at the head of the table are not performed properly.

CONVERSION TABLES

- In any case, when using such tables, try to establish mentally some order of magnitude for the quantity to be determined compared to the magnitude of the quantity in its original set of units.

CALCULATORS

- Initial Settings
- Notation
- Order of Operations
- Powers of Ten

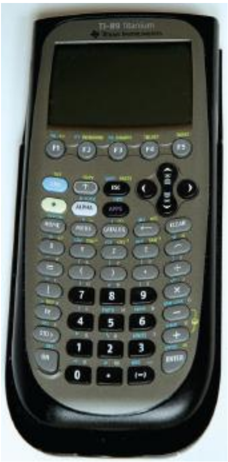

FIG. 1.5 Texas Instruments TI-89 calculator. (Don Johnson Photo)

COMPUTER ANALYSIS

- Languages
- Software Packages