1

INTRODUCTION

1.1 THE SCOPE OF ELECTRICAL ENGINEERING

It is universally agreed that Electrical Engineering is a branch of engineering that deals with the phenomena of electricity. Apart from this vague statement, however, there is no worldwide agreement on the actual scope of an electrical engineer. In particular, there are two main approaches:

- In some cases, electrical engineering is considered as encompassing those disciplines in which electrical quantities (voltages, currents) are used to transfer *signals* (e.g., in computers, radio and TV sets, etc.) and those in which electrical quantities are used to manage and transfer *energy* and *power* (electrical machines and lines, electrical household installations, etc.). This approach is, for instance, normally followed in North America.
- In other cases, electrical engineering is considered to be involved only when electrical quantities are used to *transfer* and *convert* energy and power. This approach is usually followed in Europe. This kind of electrical engineering is often called *electric power engineering*.

This book follows this second approach, hence its title. Generally speaking, the whole scope of Electric Power Engineering comprises everything needed to manage electric energy, from its generation to its final utilization.

Fundamentals of Electric Power Engineering: From Electromagnetics to Power Systems, First Edition.
Massimo Ceraolo and Davide Poli.

The word "generation" might be a bit misleading since energy cannot, indeed, be generated: the term means production of electricity by conversion from other forms of energy. For instance, the electric alternators of large oil or gas power plants "generate" electricity by conversion from mechanical energy, in turn obtained by using other machines, like steam or gas turbines. Photovoltaic panels are another example of electricity generators: they produce electric energy through the conversion of solar radiation.

The final utilization of electricity very often involves another conversion; for example, the final energy form can be heat (in heaters or ovens) or mechanical energy (in industrial electric motors, in electric cars, etc.). There are cases, however, in which electric energy is used as such; the most significant example is for supplying computers or other electronic apparatuses.

Between generation and final utilization, electric energy can be transformed several times (for instance in power transformers, which raise the voltage while lowering the current and vice versa), and transferred for distances of up to hundreds or thousands of kilometres, by means of power lines.

Indeed, it will be seen in this book, especially in Part IV, that the more power to be transmitted, the higher the required voltage level. Therefore, the power system has low voltage (LV) parts (for instance, power in homes and offices is always LV), medium voltage (MV) parts (the alternators of large power plants generate power at MV level), and high voltage (HV) and extra high voltage (EHV) levels.

All these apparatuses, which convert or transfer energy, are therefore parts of a great system, one of the largest that mankind has ever built, that encompasses the generation, transformation, transmission, distribution, and utilization of electric energy and is called a *power system*. All this can be visualized in the diagram in Figure 1.1, which shows the main functions of a power system along with the different energy forms involved.

A typical situation includes electricity generation in power plants, transformation toward high voltage in transformers, transmission toward load centres, transformation into medium or low voltage, distribution to single loads, and conversion to final usage. In the figure, the term "Bulk Generation" refers to large-scale centralized facilities, which inject their production into the transmission grid. "Distributed Generation" (DG) is instead composed of a large number of small-scale power plants, installed

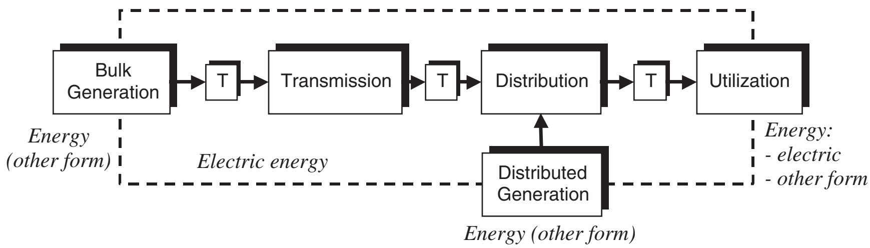


FIGURE 1.1. General structure of a (full) electric power system (T blocks indicate transformation made by power transformers).

close to the final users and directly connected to a distribution network. In the same figure, "T" represents the transformation performed by power transformers; other forms of electric-to-electric transformation are usually made inside the biggest blocks; for instance, utilization could involve a combined rectifier/inverter pair that allows maximum flexibility to the electric motor speed variation. The DG can be provided with power transformers, depending on the voltage of the generator and of the receiving network.

The outline of the electric power system shown in Figure 1.1 is much simplified, in line with the aims of this chapter. A more detailed and accurate description of the electric power system will be given in Part IV of this book.

When a *power system* is mentioned, what is usually intended is one of the very large networks that link power plants (large or small) to loads, by means of an electric grid that may be as large as a continent, such as the whole of Europe or North America. A power system, in this sense, extends from a very large power plant (e.g., having thousands of MW of generated power) right up to either the lamp that might now be lit on your table or the sockets giving electricity to loads from the nearest wall! Smaller power systems could be made of sections of a larger system. Examples are shown in Figure 1.2.

Figure 1.2a contains several components (breaker, cable, motor), which operate together and are connected to a feeding network. The subsystem represented in

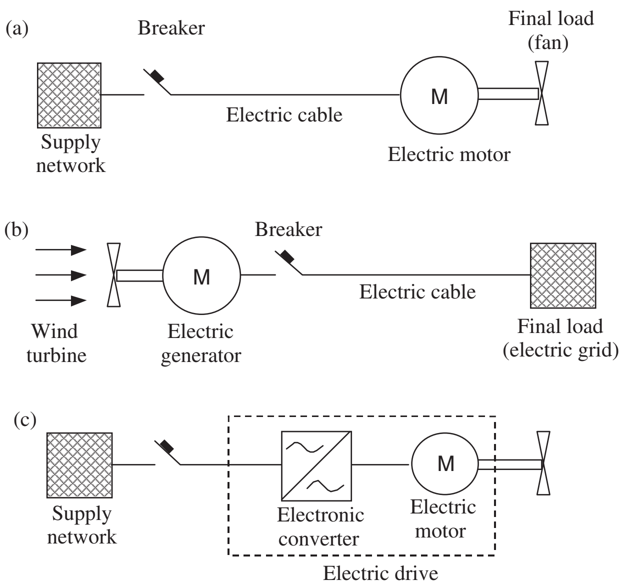


FIGURE 1.2. An electric power system fed by a supply network: a partial electric power system.

Figure 1.2a could be one of the final users of the electric energy in the utilization block shown in Figure 1.1.

Figure 1.2b contains many of the same components as Figure 1.2a, but its purpose is totally different. Instead of the fan, we have a wind turbine, which has some similarities to a large fan, but with the power flow reversed: it receives power from an air flow to produce mechanical energy, while a fan uses mechanical energy to obtain an air flow. The subsystem represented in Figure 1.2c could be one of the small power plants contained in the block of distributed generation shown in Figure 1.1.

Finally, Figure 1.2c contains a variation of the system in Figure 1.2a. The presence of the electronic converter allows much greater flexibility in the use of the electric motor and, in particular, allows variable speed operation of the fan. The electronic converter modifies electrical quantities, thus transforming *electricity into electricity*, differently from motors and generators that convert, respectively, mechanical energy into electricity and vice versa. Electronic converters tend to be increasingly present in power systems, even though they are not in evidence in the simplified diagram in Figure 1.1.

A very large number of power systems like the ones shown in Figure 1.2 operate only when connected to the mains—for example, a feeding network.

A power system such as that shown in Figure 1.1 is called a *full power system*, since its operation does not require feeding points from other electricity sources and the produced electricity is supplied to loads.

Power systems that are fed instead by an external electricity source or that produce (by conversion from other sources) electricity and convey it to a larger grid are called *partial power systems*.

There are also full power systems that are much smaller than the large power systems (such as those of Europe or North America) discussed earlier, but still, on a smaller scale, perform the basic functions of generation, distribution, and utilization of energy. An example is the small system created to feed a building yard, along with the cables and loads. Another example is the electric system on board electric cars: battery, inverter, motor, and accessory parts.

It should be stressed that a power system is basically composed of power lines and apparatuses that convert energy (*energy converters*). Power lines are relatively simple in their inner structure and do not need a great deal of explanation, especially in an introductory book.

The energy converters that are of interest to electric power engineering can be divided into two categories:

- Apparatuses for converting electricity into other forms of energy and vice versa. With reference to Figure 1.1, these are usually at the source of the system ("Bulk Generation" block), where electric energy is produced through conversion from other forms of energy and at its end ("Utilization" block), where electricity, when not used as such, is converted into other forms. Of great importance are the apparatuses that convert electricity into mechanical energy and vice versa—that is, those used for *electromechanical-energy conversion* (electromechanical converters).

- Conversion from electrical energy into electrical energy with different characteristics—that is, *electric-to-electric energy conversion*. This kind of conversion is carried out by power transformers (like those shown in Figure 1.1), but also in other situations. For instance, electricity can be converted from alternating current (AC) into direct current (DC) (using rectifiers) or from DC into AC (using inverters), and so on. This kind of conversion, not explicitly shown in the simplified diagram of Figure 1.1, is becoming increasingly frequent in power systems; each of the larger blocks in Figure 1.1 can contain electric-to-electric conversion apparatuses. For instance, an electric motor is often fed by an inverter, to form a system called *electric drive*.

1.2 THIS BOOK'S SCOPE AND ORGANIZATION

Nonelectrical engineers do not need to know the details of electric power systems; however, they need to master its basic functions in order to be able to exploit their application and to effectively collaborate with electrical engineers in more complex cases.

Since this book is intended for use in courses of one or two semesters, the authors have had to make important decisions on how deeply each topic should be dealt with. Our final decision was to focus on showing (a) how a physical system can be modelled using circuits and (b) how circuits can be analysed. Once readers have gained the ability to "solve" circuits—that is, to numerically compute currents, voltages, and power—they will have gained sufficient knowledge of the phenomena in any electric device; at that point, the way has been paved for learning more about electric machines, drives, and power systems.

To pursue its objectives, the book has been divided into the following four parts:

Part I: Preliminary Material. This part contains two very different chapters, both of which are introductory to the book's core material. Chapter 1 includes miscellaneous topics such as a discussion of the very meaning of electrical (or electric power) engineering, as well as an overview of the scope and organization of the book. Chapter 2, on the other hand, creates a bridge between the core material of this book and the student's previous knowledge. It is organized into two levels, and students can select the one most appropriate to their previous knowledge of electromagnetism.

Part II: Electric circuit Concept and Analysis. The main purpose of this part, as mentioned previously, is to show readers how to handle electric circuits. For this, we have adopted an innovative approach: readers will learn that circuits are mathematical/graphic tools to model physical systems operating with electric quantities. We will show that, because they are models, the results we obtain from mathematically solving circuits are accurate only to the extent to which they correctly model physical systems. We will also explain that they are zero-dimensional models, while actual systems are distributed-parameter, that is, three-dimensional. This explanation is useful not only for building a sound base of electrical engineering knowledge, but also as a significant example of how engineering is practiced in all of its fields.

Part III: Electric Machines and Power Converters. We saw in the previous paragraph that electric power systems contain several apparatuses to convert energy. These are the main subjects of Part II of this book.

This part combines three disciplines that are traditionally distinct: *electric machines* (machines for electromechanical conversions, plus the power transformer), *power electronics* (dealing with electric-to-electric conversion, different from that of power transformers), and *electric drives*.

The aim is to interpret the modern world, where these disciplines are strictly related to each other, and to present information in the form best suited to readers of this book, whether or not they are electric engineering students.

Part IV: Power Systems Basics. The description of power systems in Section 1.1 is very concise. Depending on how this book is used, more detailed information about the whole electric power system may be required. This is given in Part IV of the book, which contains (a) a description of the structure and operation of the system and (b) basic information about the risks of electricity for livestock and about how to prevent accidents.

Since this book is intended for courses of one or two semesters, some parts have been written in such a way that they can be omitted for shorter programmes.

Each chapter of the book starts with a “For the Instructor” box explaining the approach to be followed, along with (whenever possible) advice as to what can be safely omitted in shorter courses.

Examples of one-semester courses that can be taught using this book are:

- A course subsequent to a circuit course. In this case, Part II can be omitted and the material for the course can be drawn from Parts III and IV.
- A one-semester course on the fundamentals of electric power engineering, as the only electrical engineering course in a programme. In this case, Chapters 8, 14, and 15 can be totally omitted. If further reductions are necessary, Chapter 13 can also be omitted.

1.3 INTERNATIONAL STANDARDS AND THEIR USAGE IN THIS BOOK

1.3.1 International Standardization Bodies

Since it is written in the third millennium, this must be a *global* book. It is therefore intended for any reader from anywhere in the world. This means that the graphics and conventions for drawings and writing equations must be independent, as far as possible, of individual country preferences.

To ease the reciprocal exchange of information (and objects), common standards have been set by international organisations, in particular:

- The *Bureau International des Poids et Mesures* (BIPM), whose task is ("*to ensure world-wide uniformity of measurements and their traceability to the International System of Units (SI).*"[1] It thus provides indications on how to numerically evaluate and indicate measurements of different quantities.
- The *International Electrotechnical Commission* (IEC), which is "*the world's leading organization that prepares and publishes International Standards for all electrical, electronic and related technologies.*"[2] The IEC is one of three global sister organizations (IEC, ISO, ITU) that develop International Standards for global use.
- The *IEEE standards Association* (IEEE-SA), which "*brings together a broad range of individuals and organizations from a wide range of technical and geographic points of origin to facilitate standards development and standards related collaboration.*"[3]

Of these, the most important organization for the purposes of this book is the IEC; however, some basic information from the SI can be found in the publication [s2], which provides a good interpretation of the BIPM documents; some ISO standards, such as [s9], might also be of interest.

There are some fields of Electrical Engineering in which IEEE standards are an acknowledged important international reference; in these cases, reference is also made to IEEE standards (such as [s5] for harmonics control, quoted in Chapter 8).

A detailed presentation of standards is far beyond the scope of this book, but a systematic adoption of all the agreed standards (with some minor deviations) will help the reader to become accustomed to them and to remember them for many years to come.

1.3.2 The International System of Units (SI)

The International System of Units, SI[4] for short, defines the units of measure to be used all over the world, for measuring the different quantities used in any field of science or technology, from physics to engineering.

However, there are many situations in which people do not comply with the SI and use other units of measure. For instance, aeroplane altitudes are commonly indicated in feet, ship speeds in knots, and engine powers in HP. This is totally unjustified in the majority of cases. Dealing with thousands of different units of measure traditionally used in different countries, and with the corresponding conversion factors, only adds

[1] Text drawn from [s1].
[2] Text drawn from [s3].
[3] Text drawn from [s4].
[4] This international abbreviation comes from the French version of the name: Le Système International d'Unités.

TABLE 1.1. The Five Base Quantities and Units Considered in this Book

Quantity	Unit Name	Unit Symbol	Preferred Symbols for the Quantity
Length	metre[a]	m	*l*, *s*, *r*
Mass	kilogram	kg	*m*
Time	second	s	*t*
Current	ampere	A	*I*, *i*
Thermodynamic temperature	kelvin	K	*T*

[a]The American spelling "meter" is also acceptable. In this book, whenever there are differences, the British spelling is always chosen, as defined in the *Oxford English Dictionary*.

undue effort and uncertainty to the work of technicians as well as ordinary people. The use of non-SI units, except in very limited cases for which specific justifications may exist, is even more questionable in books addressed to the younger generations since this could cause the perpetuation of these errors, thus slowing, if not jeopardising, the whole process of universal dissemination of the SI and the benefits it can bring.

In this book, therefore, the SI units of measure are always used, with virtually no exceptions. Only units considered by the SI itself to be "non-SI units accepted for use with the SI" are used, such as minutes (min), hours (h), and days (d), because of their widespread use in everyday life.[5]

Students are strongly advised to use SI units as much as possible. Once accustomed to them, they will find it natural to use them always. This way, one day in the future, the entire population (or most of it) will use a single unit for a single quantity, which will make life easier for everyone.

The SI defines seven *base units*, which by convention are independent, as well as many other derived units, one for each quantity, expressed in relation to the base units.

In this book, only quantities in relation to a subsystem of five of the SI base units will be used; the base units of interest of this book will thus only be those shown in Table 1.1. Please note the style of writing in accordance with international standards, applied both to base and derived units:

- The initial letter of a unit is in lowercase and no accents are used (see the example of the unit for electric currents).
- The symbol of a unit *must* always be written either uppercase or lowercase as given. For example, kilogram has the symbol kg (not Kg), ampere A, and so on. Symbols may be composed of more than a single letter (such as Pa for pascal, the standard unit of pressure).[6] Finally, symbols must be written in roman

[5]For a complete list of such SI-accepted, non-SI units and notes on their usage, see [s2].

[6]The ISO standard provides a strict rule for the case of units: when the unit is represented by the initial of a scientist's name, it must be uppercase: V for volt, A for ampere, and so on; otherwise it should be lowercase: kg for kilogram, lx for lux, and so on. The only exception is the liter, for which the use of "L" instead of "l" is accepted, to avoid confusion with the number 1 (one).

(not italic) type, regardless of the type used in the surrounding text, and must not be followed by a dot, unless at the end of the sentence (e.g., "a current of 2 A is generated", *and not* "a current of 2 A. is generated").

As far as temperature is concerned, thermodynamic temperature is mentioned in Table 1.1 because in the SI it is used to define the Celsius temperature, using the very well-known equation

$$t = T - T_0$$

where t and T are the same temperature, measured in degrees Celsius and kelvin, respectively, while the reference temperature T_0 equals 273.15 K.[7]

When the numerical value of a quantity is given, its unit of measure must be shown alongside its numerical value: $I = 2$ A means that I is twice the value of the SI standard current, the ampere. What is not widely known is that the same expression can also be written I/A = 2. As surprising as this might be, it is very rational: the numerical value of any quantity is always the ratio of the quantity to the reference value (in this case the SI base quantity).

This way of expressing units of measure of quantities is recommended also when the unit of measure refers to several numerical values, such as in tables or plots. This is visually expressed in the following tables, in which the recommended way is compared to another common way of expressing units of measure in table or plot headings—that is, within square brackets:

RECOMMENDED VERSION

Object	T/K
one	216
two	218
three	222

NONRECOMMENDED VERSION

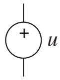
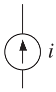
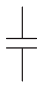
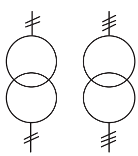
Object	T[K]
one	216
two	218
three	222

1.3.3 Graphic Symbols for Circuit Drawings

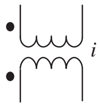
The circuit drawings in this book are written according to the latest international standards. A summary of the symbols used is contained in the following table.

[7]Here there is a clear exception to the general rule requiring the units of measure to be lowercase: the addition of word "degree" changes the word "Celsius" from a unit name to the name of the scientist, thus requiring an initial capital.

The following symbols are a selection from International ISO/IEC/IEEE standards ([s6], [s9] and [s10]). In rare cases some small deviation from the standard is used, and the reason for this choice is to be found in the *notes* column.

Component	Symbol	Notes
Voltage source		(1) the vertical line represents the ideal wire on which the source is applied. (2) the "+" sign indicates the polarity of voltage u when $u > 0$; for greater clarity, an optional "–" may be added opposite "+".
Sinusoidal voltage source		Voltage source symbol can also be used.
Current source		(1) The vertical line represents the ideal wire on which the source is applied. (2) The arrow sign indicates the direction of current i when $i > 0$.
Resistor		(1) The aspect ratio should be 3:1. (2) In this book, especially throughout Chapter 2, rectangles also model generic branches, but they will have a different aspect ratio (see next row).
Passive element (with impedance)		In AC circuits the resistor symbol is commonly used to represent a generic *passive element* (with impedance)—for example an *R–L* (resistor-inductor) or an *R–L–C* (resistor-inductor-capacitor) series.
Generic branch		Generic branch, which can be a resistor, an inductor, a source, or any other component or combination of components. Aspect ratio: 2:1 or less.
Inductor		The aspect ratio should be 4:1.
Capacitor		
Transformer—form 1		The two symbols refer to single-phase and three-phase transformers. They are used in single-line representations only.

(*Continued*)

Component	Symbol	Notes
Transformer—form 2		The IEC does not provide specific symbols for *ideal transformers* (circuit elements) and *transformers* (machines that can be modeled with varying degrees of detail). In this book the ideal transformer will be indicated using a letter *i* in the scheme.
Coil		The IEC considers this symbol to be obsolete. However, it does not provide a specific symbol for coils. In this book, coils are intended as physical objects (usually with some resistance and inductance) while inductors are ideal components with inductance only.
Three-phase synchronous machine		The IEC symbol requires the textual information to be as follows: • M for asynchronous motor • G for asynchronous generator • MS for synchronous motor • GS for synchronous generator In this book, deviation is made from this standard, since circuit elements represent objects, and the object is the synchronous or asynchronous machine; *motor* and *generator* are just operating modes of the object.
Three-phase asynchronous machine		

1.3.4 Names, Symbols, and Units

Equations relating to electric phenomena and circuits appear in this book according to the latest international standards. This is because of the *global* nature of this book and to ease communication between people of different countries or regions of the world. Readers can thus be confident that the graphic conventions used throughout the book closely match (with very few, well-motivated exceptions) those of internationally agreed standards, and they are strongly advised to become familiar with them and to use them now and in the future.

The basic rules set by these standards for writing SI units of measure have already been presented in Section. 1.3.2. Other rules, closely followed in this book, are as follows:

- Symbols that identify physical quantities are written in italics (e.g., V or v for potential, V for volume, m for mass, I or i for currents, and so on.[8] Subscripts are

[8]The only exception in this book, in line with the majority of books, regards quantities represented by uppercase Greek characters: these are not written in italics, simply because this makes them easier to distinguish. For example, when a mechanical speed is indicated using an uppercase omega, it will be written as Ω rather than Ω.

written in italics when they refer to physical quantities (e.g., C_p for thermal capacitance at constant pressure p), but in roman (upright) in all other cases (C_{g} for gas thermal capacitance, U_{av} for average voltage).

- Vectors and matrixes are represented using bold type (e.g., $\boldsymbol{E}$ and $\boldsymbol{B}$ for electric and magnetic fields);
- Time-varying quantities, whenever possible, are expressed using lowercase letters (such as i for currents, u for voltages) while quantities that are constant over time are expressed using uppercase symbols (I and U, respectively, for current and voltage).
- Complex numbers, as stated in [s9], are indicated by underlining the related symbol; for example, $\underline{U} = \underline{Z}\,\underline{I}$ is Ohm's law for alternating circuits, expressed by means of complex numbers. Conjugates of complex numbers are referred to using an asterisk: $\underline{Z}^*$ is the conjugate of $\underline{Z}$.

In addition to these general rules, the following additional conventions, compliant with standards, though not mandatory, are used in this book:

- When sinusoidal voltages are given, their peak values are indicated by the peak sign "^" above the relevant symbol (e.g., the peak of a sinusoidal voltage u is $\hat{U}$).
- Symbols representing integer numbers (e.g., $i, j, k, \ldots$) are shown in italics since this makes them easier to read and is very common practice in books and articles.

The names of the quantities used in the book, their symbols, and their unit of measure are also taken from the above-mentioned international standards and are shown in the following table.

The official standard has been simplified in some cases. For instance, "electric field" is used instead of the official name "electric field strength." This is for reasons of both simplicity and rationality; other names would otherwise also need to be changed: for instance, "electric current intensity" would have to be used instead of "electric current."

Quantity	Symbol	Unit		Notes
		Name	Symbol	
Electric potential	v, V	volt	V	
Voltage, potential difference[a]	u, U	volt	V	
Electric current	i, I	ampere	A	
Electromotive force	e, E	volt	V	
Current density	J	ampere per square metre	$\mathrm{A/m^2}$	
Resistance	R	ohm	Ω	
Conductance	G	siemens	S	
Inductance (or self-inductance)	L	henry	H	
Impedance	Z	ohm	Ω	

(*Continued*)

Quantity	Symbol	Unit		Notes
		Name	Symbol	
Electric field electric field strength	$\boldsymbol{E}$	volt per metre	V/m	
Electric flux density	$\boldsymbol{D}$	coulomb per square metre	C/m^2	
Permeability	μ	henry per metre	H/m	$\boldsymbol{B} = \mu \boldsymbol{H}$
Magnetic field, magnetic field strength	$\boldsymbol{H}$	ampere per metre	A/m	
Magnetic flux density	$\boldsymbol{B}$	tesla	T	
Magnetic flux	ϕ, Φ	weber	Wb	
Linked flux	Ψ	weber	Wb	
Permittivity	ε	farad per metre	F/m	$\boldsymbol{D} = \varepsilon \boldsymbol{E}$
Phase difference	φ	—	—	
Reluctance	$\mathcal{R}$	one per henry	H^{-1}	
Resistivity	ρ	ohm metre	Ωm	
Volumic charge[b]	ρ	coulomb per cubic metre	C/m^3	

[a]The name "voltage", commonly used in the English language, is the term preferred by IEC, but is an exception to the principle that a quantity name should not refer to the name of a unit. Another term, equivalent to voltage, is "tension".
[b]Also (known as) volume density of charge.

1.3.5 Other Conventions

An important decision, and one for which no solution is suggested by international standards, regards the decimal marker. The 22nd General Conference on Weights and Measures (CGPM) decided in 2003 that "the symbol for the decimal marker shall be either the point on the line or the comma on the line."

In this book the decimal marker is shown as a point on the line.

For vector products, the two following symbols, again from International Standards, are used everywhere:

- Result $\boldsymbol{c}$ of *dot* product between $\boldsymbol{a}$ and $\boldsymbol{b}$: $\boldsymbol{c} = \boldsymbol{a} \cdot \boldsymbol{b}$
- Result $\boldsymbol{c}$ of *cross* product (or *vector* product) between $\boldsymbol{a}$ and $\boldsymbol{b}$: $\boldsymbol{c} = \boldsymbol{a} \times \boldsymbol{b}$

1.4 SPECIFIC CONVENTIONS AND SYMBOLS IN THIS BOOK

In addition to conventions stipulated by relevant international standards, steps have been taken to ensure a uniform style throughout this book. This additional standardization is in the form of simple conventions as shown in this section.

1.4.1 Boxes Around Text

For easy reference, boxes are used to emphasize very important pieces of information. The following types of boxes are used:

> **Convention:** *Name of convention*
>
> Contains adopted conventions, such as the one used to indicate voltage polarity. Normally the adopted conventions are drawn from International standards; when this does not occur, the decision is commented on and justified.

> **Definition:** *Name of definition*
>
> Contains the definition of new concepts (such as a circuit) or quantities (such as the ampere as unit of measure of a current).

> **Law:** *Name of law*
>
> States some fundamental laws of electromagnetism or circuits, such as the charge conservation law or Kirchhoff's laws.

> **Result:** *Name of result*
>
> The main results of the analyses carried out are evidenced in boxes, so that they are easily spotted at a glance.

> **Rule:** *Name of rule*
>
> Practical rules to be applied to obtain particular results are also boxed. An example is the rule that allows a circuit-like physical system to be dealt with using the abstract circuit concept.

1.4.2 Grayed Boxes

Sometimes the text is evidenced in grayed boxes. Two types are used: *more in depth* boxes and *for the instructor* boxes.

The "more in depth" boxes can be found throughout the chapters, and offer in-depth insight to the basic concepts in the general text. Although not essential for acquiring a basic knowledge of the topics, their visual appearance is such that the reader is stimulated to read (and possibly study) them.

The "for the instructor" boxes are to be found only at the beginning of a chapter, just below the table of contents, and explain the rationale behind the choices made, to help teachers plan their presentation of topics in class.

The appearance of these boxes is as follows:

> ***More in Depth***
>
> This is a simple *more in depth* box.

> **For the Instructor**
>
> This is a simple *for the instructor* box.

1.4.3 Terminology

Terminology in any textbook should be free from strict standards. However, when a lot of books share the same terminology, this is useful for readers wishing to refer to several sources. Therefore, whenever possible, terms drawn from International Standards such as [s4] or [s7] are used.

As regards circuits, some deviation from standards was advisable in some cases; therefore in Chapter 2, in the section "definitions", the most important definitions relating to circuits are reviewed, and deviations from International Standards evidenced.

1.4.4 Acronyms

Minimum use is made of acronyms to facilitate reading. The only acronyms used in the book, also written in full on occasion, are those shown in the following table:

Acronym	In Full
AC	alternating current
DC	direct current
EMF	electromotive force
PM	permanent magnet
PPU	power processing unit
KCL	Kirchhoff's current law
KVL	Kirchhoff's voltage law
rpm	revolutions per minute
rms	root mean square

1.4.5 Reference Designations

A selected reference list is included at the end of this book. The reference number contains a letter indicating the nature of the reference. For instance, [s2] is an international standard (as indicated by the letter “s”), [bc1] is a circuit-related book (as indicated by the letter “c”), and [p2] is a scientific paper.