An Engineer's Guide to Technical Writing

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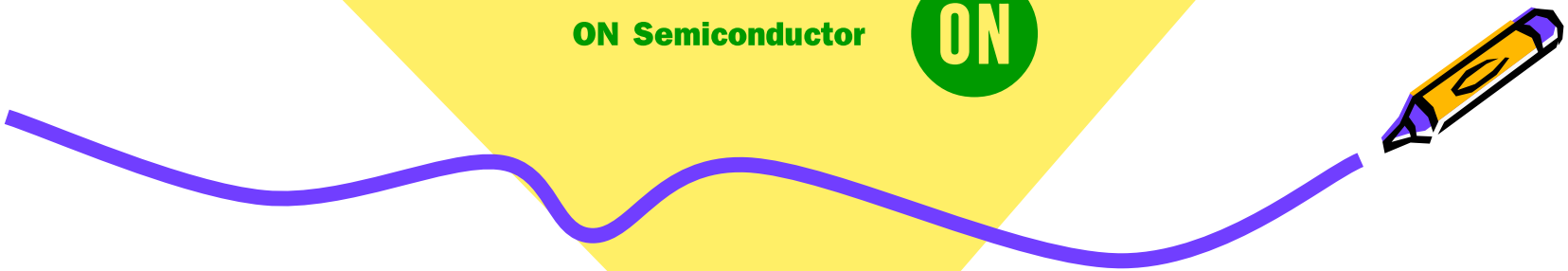
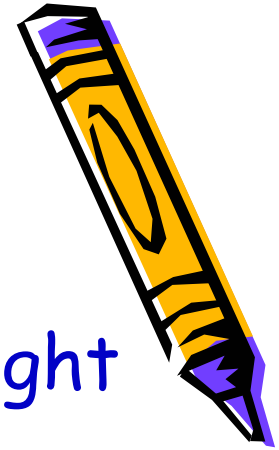


Situation



- We learned to work problems and get right answers.
- We learned to write reports and papers, but most of us didn't learn to get them "right."
- Most of us weren't even given the tools to find out if we were right or not!

Getting it Right

- The reference material is out there!
- I did a Google search on the Web:
  - "Technical Writing" → 2,440,000 hits
  - "Technical Writing Guides" → 378,000 hits
  - Each search took less than 0.3 seconds.
  - Some were lousy! (I didn't read them all.)
  - Good news: *You don't need them all!*

References

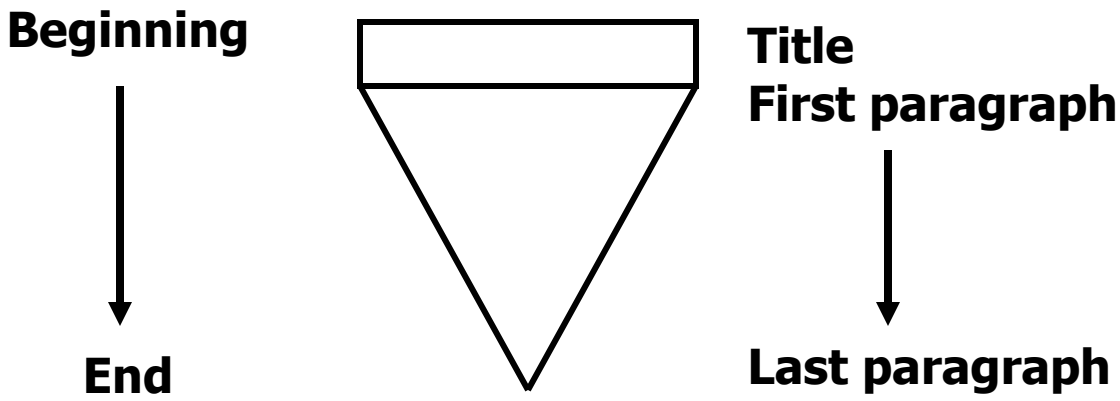
- Good English dictionary (e.g. Webster's II New Collegiate Dictionary)
- IEEE Dictionary (IEEE Std 100)
- Style Guide (Strunk & White or Gregg)
- Metric System (SI units) - ANSI Std 260.1
- Composition Guide (Standler, this paper, etc.)
- Ground rules for the journal (IEEE, etc.)
  - Author's kit, rules, examples
- PSMA Web site (psma.com) – free downloads

Structure: 3 Types
(Pick One)

- Newspaper
  - Headline & first paragraph tell main msg.
  - Subsequent paragraphs give details.
- Research
  - Overview given in the abstract or intro.
  - Work progresses to a conclusion.
- Survey
  - Multiple points are covered.

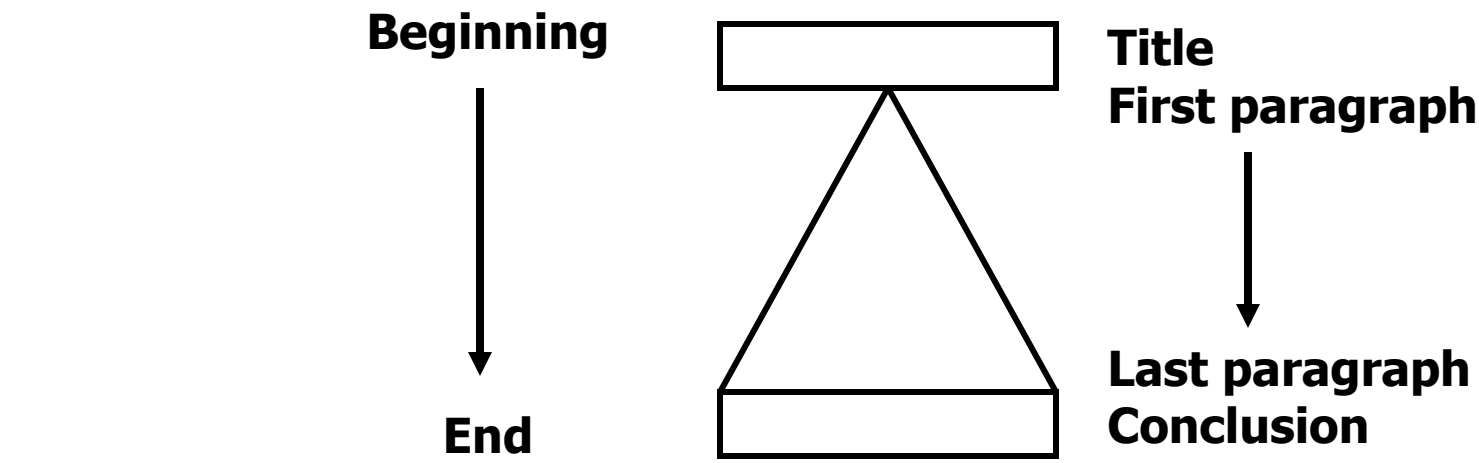
Newspaper

- Headline (title)
- Main point covered in first paragraph
- More details as article progresses



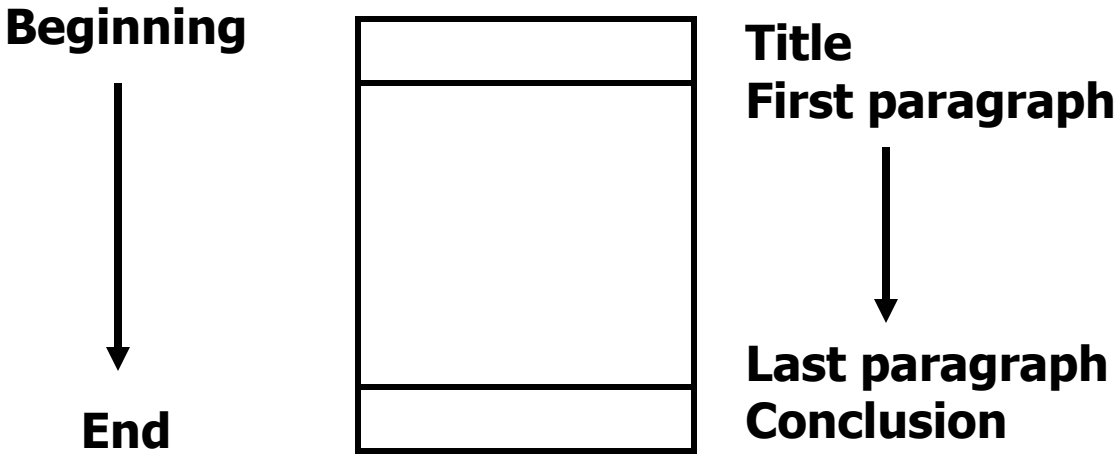
Research

- Title
- Overview (abstract or introduction)
- Article describes solving the problem.

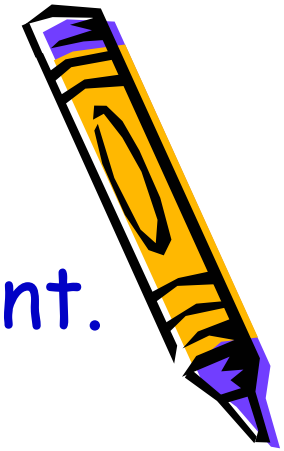


Survey

- Title
- Overview (abstract or introduction)
- Multiple, equal-weighted topics covered



Paragraphs Are Important



- Each paragraph expresses one point.
- Usually, the first sentence states the point, and the remainder explains it.
- Sometimes, it's the opposite---the paragraph ends in the conclusion of the point.
- In either case, it's ONE point.

Formula for Success

- Define the message of the paper
  - It should be clear in YOUR mind.
  - If you can't do this, how can anyone get it?
- Organize the project
  - Outline the content.
  - Do the research and organize the results.
- Write the paper to convey the message.

Writing the Paper

- Choose the format.
  - Page setup (margins, etc.)
  - One column vs. two column
  - Hierarchy of paragraphs
  - Font types and sizes
  - Labeling of tables and figures
- Establish the above; be consistent!

Anything Wrong Here?

- Wizard Labs present's a new DC/DC Power controller with High Supply rejection, 500MHZ bandwidth, a three-nanovolt offset Error Amp and 5-amp output drive.

A Dozen Boo-Boos

- Wizard Labs present's a new DC/DC Power controller with High Supply rejection, 500MHZ bandwidth, a three-nanovolt offset Error Amp and 5-amp output drive.

Corrected Version

- Wizard Labs presents a new dc-dc power controller with high supply rejection, 500 MHz bandwidth, and a 3-nV-offset error amplifier with an output drive of 5 A.

Cases

- Sentence case---blah, blah.
  - Capitalize first letter of first word.
- lower case except RF circuits
  - Use lower-case letters, with exceptions.
- UPPER CASE
  - Use all upper-case letters.
- Title Case in Headlines
  - Capitalize important words.
- SMALL CAPS (see font, effects in Word)

The Details

- SI units (the modern metric system), their symbols and usage (space between the value and the unit, etc.) are international standards and are not negotiable.
- Hyphens, capitalization, plurals, punctuation, etc. are well-defined in authoritative style guides.
- Use them properly. Like it or not, we are judged by our writing.

Common Errors

- **Correct**
  - 10 mV, 0.22 ohm, 5 ns
  - Our dc-dc converters
    - Use hyphen for "to"
  - Ac-dc supplies are…
    - Cap. A for sentence case.
  - The Best DC-DC Bricks
  - The Best Dc-Dc Bricks
  - Good FETs and ICs
  - The FET's voltage…
  - The FETs' drives…

- **Incorrect**
  - 10mV, .22ohm, 5 nSec
  - Our DC/DC converters
    - The "/" means "or"
  - AC-DC supplies are…
    - Don't capitalize all 4 in sentence or lower case.
- Note: In title case, both DC-DC and Dc-Dc are OK.
  - Good FETS and IC's
  - The fet's voltage…
  - The FETS' drives…

Symbols or Names

- Most SI units:
  - Named for famous scientists (Ohm, etc.)
  - YET: The name is not capitalized.
    - 15 volts, 10 ohms, 22.5 watts.
  - The symbol is capitalized.
    - 15 V, 10 Ω, 22.5 W (spell ohm if no Ω avail.)
- Avoid abbreviations (amps, etc.)
- Be consistent in text (names or symbols).
- Use multipliers properly (mA, kW, kΩ, kWh)

Thanks for Helping to Stamp out Sloppy Writing!

- Be a leader
  - DON'T believe everything you read!
  - Gather your own references and use them.
- Practice good writing---everywhere.
  - It's easier than using two sets of rules.
- Why be misjudged by your writing, when it's so easy to be right!

An Engineer's Guide to Technical Writing

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Abstract---In spite of the abundance of reference material on technical writing, the preparation of technical papers remains a challenge for many engineers. This work brings together several aspects of preparing technical papers: organizing the message, formatting it into a presentable paper and using symbols, references, etc. accordance with established practices.

I. Introduction

It's time to bury the myth that engineers can't write. The abundance of excellent papers appearing at major IEEE conferences clearly proves otherwise. Excellent research is being communicated effectively to the industry and academia as well. What's clear is that many engineers like to write and take pride in communicating the results of their work. What's missing from this picture is a clear, concise and brief guide to handling some of the details. The most critical need is for a simple guide to units, symbols, punctuation, acronyms and other matters somewhat unique to technical writing. Most engineers want their written work product to be just as good as their analytical work products, but most do not know where to look for help. Most of the answers are in this paper.

A. The Contributions of This Work

This paper summarizes the results of considerable research and experience in technical writing. The information obtained is organized to make the job of producing clear, effective technical documents as easy as possible for the author. It will save countless hours of digging through a sea of references, becoming confused with conflicting results, and expending undue effort to produce a flawed document based on erroneous guidance.

B. Specific Results

The results of this work are threefold: 1) A brief guide to writing a technical paper, based on a review of several excellent, comprehensive references on the subject, 2) A bibliography of carefully-chosen and available writings, specifically annotated to guide the reader quickly to the answer to his question, and 3) An appendix of the most common errors, to be used as a handy reference in all forms of technical writing.

C. Methods Used

The research in the area of technical writing is based on the typical engineer's curiosity and inherent desire to do things "right." Faced with technical writing tasks early in his career, the author began probing for guidance. Technical papers were reviewed for style and format and used as a guide in writing a new one. Existing instruction manuals were used as a guide in writing another. New-product releases in trade periodicals were used as a guide in announcing a new product. Going through these exercises brought forth a revelation: The material in print contains many conflicts! It became clear that in the technical sections of these documents, either there were no standards, or the authors weren't following them. There were, of course, errors and conflicts in the non-technical aspects of the writing, but these are easy to resolve by the use of well-known references (dictionaries, language texts, style guides, etc.).

Based on these years of observations, a hunt began for existing standards---ones that might define how to handle the technical content of the writing. Conducting this hunt today, with the help of the Internet and extremely sophisticated searching tools, is easier by orders of magnitude than in the past.

D. More results of the study

The number of conflicts in handling units, symbols abbreviations of technical terms in the trade press is truly astounding. Assuming most writers want to do a good job, it is then obvious that they don't know where to go for answers to their questions, or they are using poor sources for guidance. In reality, it's probably a combination of the two. One thing is for sure: using an issue of any of the latest magazines is NOT the answer!

It turns out that all of the information exists. Technical writing is not new. As a matter of fact, an Internet search using google.com and the key words, *technical writing*, yielded 2,440,000 references in 0.2 seconds! Narrowing this search down to *technical writing guides* produced 378,000 references in 0.28 seconds (tough job---three key words---took another 80 ms). Let there be no further doubt---the information age is here). There are scores of publications on the subject. Some, of course, are specific to particular technical fields. Others are specific to particular kinds of writing, such as reports, theses, etc. This variety simply makes it more difficult to find references that are directly useful to an engineer in preparing a conference paper. It's even more difficult for foreign students, as they struggle through this maze in the environment of English as a second language.

There have been some valiant efforts to solve this problem, and some of these have achieved excellent results.

1) Virginia Tech, with its unusually large population of Asian graduate students, produces a plethora of credible technical papers. There certainly are many reasons for these successes, including an exemplary faculty. In addition, there is an impressive collection of writing guides on their Web site at http://filebox.vt.edu/eng/mech/writing. This site includes contributions from U. of Illinois, Georgia Tech, and U. of Texas. It is undoubtedly one of the best collections of guidelines for students and professionals as well. Interesting, however, is the total lack of references to the international standards regarding SI units and standards that define how these are used in writing technical documents. It's no wonder that many of the students' papers submitted to the conferences have the technical content very well organized, and yet don't comply with simple rules like separating the value from the unit (write "10 kVA," not "10kVA") or using "ac" not "AC" as the abbreviation for alternating current.

2) The IEEE Dictionary (IEEE Std 100) tells us that AC is the abbreviation for acoustic coupler, and ac is the abbreviation for alternating current. Somehow, this information is not communicated. As a matter of fact, it would be interesting to find out how many IEEE members know of the existence of the IEEE Dictionary!

3) Webster's II New College Dictionary tells us very clearly that the slash, or virgule (/), means "or" as in "and/or," or "per" as in "miles/hour." There is not even a hint that it might be used for "to" as in ac/dc, and yet we see this one often. Actually, we see "AC/DC even more often---two sins for the price of one! It is correct to write "ac/dc input," when meaning the input can be ac or dc, but it is certainly wrong to use "ac/dc converter," when the meaning is that the converter converts ac to dc. The IEEE Dictionary explicitly defines "dc-dc converter" as "A machine, device or system, typically combining the functions of inversion and rectification, for changing dc at one voltage to dc at a different voltage." Note the use of the hyphen and the use of lower-case dc in this definition.

It is not the purpose of this paper to include all of the information needed to compose a top-quality paper. It wouldn't fit into 8 pages or a 20-minute talk. It is the purpose of this paper to point the reader to enough of the credible references needed to get the job done, and to address some of the most common pitfalls evident in today's writing. The list of references will be carefully chosen, to avoid any misinformation or wasting of the reader's time.

II. Construction of a Successful Paper

The purpose of a technical paper, manual or report---or even an email---is to convey information to the reader. Common sense tells us that the communication is not complete until the recipient has understood it. Getting the message usually means much more than receiving the document. It means receiving the message that the author wished to convey. To do this it is essential that 1) The author has the message well defined for himself, 2) He has organized it in a logical order and 3) He has written it in such a way that the intended audience will understand it in the way he wished it to be understood.

In organizing the paper a good approach is to do what many successful teachers do, and that is, "Tell them what the message will be, then deliver the message, and then tell them what the message was." In other words, write an introduction that gives a preview of the message, then write the message, and then write a concluding section that summarizes what the message was. Obviously, this leads to the avoidance of a message that has a large number of points, unless they are organized in a very clear and logical order.

A. Doing the research and organizing the material

It is not necessary that the research be completed before the organization begins. It may be that the idea to write a paper on a given subject occurs before any research is done. Or, the research may be complete, and the idea of writing a conference paper or journal article may come afterwards. The approach to each of these is different---in the former case the paper may be outlined, then the research is done to answer the questions posed in the outline and provide backup for a message. In the latter case it is reasonable to review the research and organize it into a message that will convey the results effectively. This may mean prioritizing the material, organizing it in chronological order, or a combination of the two. Before the age of personal computers, this was often done by putting individual thoughts, research facts, and quotations on cards and then sorting the cards in logical manner as they would appear in the paper. Today this is easily done on the computer, sorting folders, files, paragraphs, etc. in a word processor.

B. Format

The choice of format for the paper can be overwhelming to the novice, due to the near-infinite formats one sees in print. Magazines, technical journals, conference proceedings and commercial presentations are all different. This leads the writer to the question, "Is there really a right way to do this, and how can I possible sort this out?" The answer is simple: Obey the rules of the publisher! Most publishers have them, and they are not secret. One must simply obtain them and follow them. In the case where the paper must be written without a planned publisher, it is best to pick a format appropriate for the type of paper and reformat it later if necessary. This paper, for example, has been prepared in strict adherence to the instructions for preparing manuscripts for APEC 2004. It is available on the IEEE Web site at this address: www.ieee.org/organizations/pubs/confpub. The conference ID is apec04 (case sensitive). Most professional societies have format guidelines available. In the case of this one, the details include the fonts, type sizes, line spacings, margins, captions, handling of footnotes, references, and the labeling of figures and tables. In the case of a well-established professional conference such as APEC, there is very little need for guesswork. In the case of less formal publications where a guide is not available, one can begin with a rigorous one and

adapt it to suit the situation. For example, in an informal newsletter one might use the IEEE format, but change the two-column format to one column, and avoid the roman numerals for the section heads. Most word-processing software packages contain canned formats. Microsoft Word contains several, and includes a suggestion of fonts for the headings. On the toolbar under *Format*, see *Styles and Formatting*.

C. Be consistent

Part of the rationale behind the established format is to avoid inconsistent use of headings, fonts, case, etc., as this is often a distraction to the reader. It's really part of the system of getting a message communicated. A reader who is not distracted by format, misspellings, improper use of symbols and other things that annoy him is more able to concentrate on reading and understanding the author's intentions. Also, careful formatting will enhance the readability of the paper.

D. A matter of case

Proper and consistent use of the various cases (lower case, upper case, etc.) is important in the quest to avoid distractions. The reader may not realize that his discomfort is caused by sloppy use of the various cases, but the effect is, again, that the message isn't received as easily as it could be. The most common cases are 1) lower case, 2) UPPER CASE (sometimes called "all caps"), 3) Title Case (as used in titles, where all major words are capitalized), 4) Small caps---all upper case letters, and a larger font to indicate capitalization, as in the section headings herein, ("I. INTRODUCTION") and 5) Sentence case (where the first word of a sentence is capitalized). Most word processors contain "Case" choices under their "Format" command in the toolbar. By highlighting a section of text and then using the Format command, one can change the case of the entire highlighted section.

It seems obvious to use title case when writing titles, and sentence case for sentences. But what about the headings of columns in tables, or the names of figures or tables? The guides for formal conference papers such as this one list the rules clearly. In the absence of such guidelines, the author has some flexibility but should insist on setting ones own guideline and following it consistently. A very common error is to capitalize words that shouldn't be capitalized. In ordinary text, only proper names and symbols should be capitalized. For example, it is usually improper to write, "The conference was about Power Supplies and their related Components." It is also improper to capitalize a phrase just because its abbreviation or symbol is capitalized. For example, one should write, "The testing of the power factor correction (PFC) section was completed." Power factor correction is not a proper name.

E. Use of the apostrophe

A common error is the misuse of the apostrophe, and this is a distraction to readers who know better. The apostrophe is not used to form a plural unless confusion might otherwise result (a rare occurrence). For example, one would not write, "The circuit used four MOSFET's." The plural of FET is FETs. However, one would write, "dotting the i's" because avoiding the apostrophe would result in "dotting the is." It is incorrect to write, "It's circuits were complex." It's is a contraction for "it is" and one would not use the apostrophe to form the possessive, any more than one would use it in the possessive pronouns "his" and "hers." It is, however, correct to write "The FET's resistance was high (singular possessive) and the FETs' (plural possessive) prices were all too high." The reason is that FET is not a personal pronoun.

III. UNITS AND SYMBOLS

Technologists are faced with an additional set of writing challenges: the handling of units and symbols. Fortunately, there is a system of units and symbols recognized the world over, helping us to communicate across language barriers and between technical disciplines. It is the modern metric system. The units, symbols and a guide for their use are found in IEEE/ASTM SI 10-1997, Standard for Use of the International System of Units (SI): The Modern Metric System. It is an official standard of the Institute of Electrical and Electronic Engineers (IEEE) and the American Society for Testing and Materials (ASTM). It is also recognized as an American National Standard (ANSI). The abstract appearing on the first page of the Standard sums it up quite well: "Guidance for the use of the modern metric system is given. Known as the International System of Units (abbreviated SI), the system is intended as a basis for worldwide standardization of measurement units. Information is included on SI, a list of units recognized for use with SI, and a list of conversion factors, together with general guidance on proper style and usage." Clearly, this standard can be used as the primary reference for the units and their application in our writing. Appendix A contains a list of the most common SI units and their symbols.

A. SI units and their symbols

One of the advantages of the SI units is their universal acceptance. Because of this, it is generally not necessary to explain them in technical writing. Their use presupposes that the reader will find them intelligible. When an unfamiliar unit symbol is first used in text, it should be followed by its name in parentheses, or the name should be given with the symbol in parentheses; the symbol may be used alone thereafter [1].

Many electrical quantities are named for famous scientists, but the names of the units are not capitalized. However, their *symbols* are capitalized. For example, the SI unit of frequency is the hertz, and the symbol is Hz. Hertz would be capitalized at the beginning of a sentence, as shown here, or in title case.

Always separate the value from the unit symbol that follows, as in 10 mV or 25 ^{O}C. This rule is not negotiable, and yet most schematic-capture CAD packages force one to disobey it. The world is not perfect. It is also incorrect to attach letters to a unit symbol as a means of giving information about the quantity under consideration. Thus,

Vac for "V ac" is unacceptable [1]. When a quantity is used in an adjectival sense, a hyphen is often used in lieu of a space between the number and the unit name or between the number and the symbol. For example, write, "A 2-meter antenna," or state that the length of the antenna is 2 meters. Exception: No space is left between the numerical value and the symbols for degree, minute, and second of plane angle. For example, "Angle B is 55^{O}."

Use symbols, not informal abbreviations, for units. For example, use "A," and not "amp," for ampere. Sometimes these abbreviations do not survive translation to another language.

Be consistent in the use of the format of units. It is acceptable to write out the names of units, but avoid mixing this practice with the use of unit symbols. For example, avoid "The signal level of 50 watts was applied to the load of 75 Ω." Use 50 W and 75 Ω, or 50 watts and 75 ohms.

F. The use of Greek letters

The unit of resistance is the ohm, and the symbol is the upper-case Greek letter, Ω (omega). The symbol for kilohm (thousand ohms) is kΩ. When the symbol is not available, one can write kOhm. Note the capitalization of the first letter of ohm, to avoid a confusing (or at least ugly) "kohm" and yet there is no capitalization when writing kilohm in text. The reason for this is that one is a symbol (kOhm with an unavailable Ω) and the other (kilohm) is the name (not symbol) written in text.

G. Compound prefixes

Compound prefixes are not to be used. Not only are they not allowed, but also their use is a clear indicator of the chronological age of the author! Do not write mμs for one billionth of a second. The correct notation is ns (nanosecond).

IV. Use of Capitals

There is a tendency to over-capitalize, particularly in technical writing. Somehow, it is tempting to capitalize the name of on object, function or topic just because it is important or familiar. This is a mistake. Doing so is like "calling wolf" too often---the audience becomes numb to it, and the effect is diminished. The Gregg Reference Manual [5] is one of the most comprehensive references on this subject, devoting over 20 pages to it. In brief, capitalize the first word of:

- Sentences.
- Every *proper* noun (the official name of a person, place or thing).
  - – Phoenix, Arizona
  - – Bill Gates
  - – Flight 403
  - – a Pulitzer Prize
- Quoted sentences (Congratulations!)
- An independent question in a sentence. (The question is, Which car is it?).
- Imaginative names and nicknames that designate particular person, places or things.
  - – a Big Mac
  - – the Establishment
  - – Generation Xers
- Each item listed in a list or outline.
- The first word after a colon if the material after the colon can stand alone as a sentence (doesn't simply modify the thought expressed in the first part).
- The material after a colon where the material before the colon is a short introductory word.
  - – Note: Be careful of the trap.
- Both parts of a hyphenated word when in title case.
  - – The Lead-Free Conference 2004
- Names such as marketing or engineering when they are used alone to designate a department within an organization.
  - – I'll call Joe in *Engineering* first.
  - – BUT: Talk to our *engineering* people first. (Here, *engineering* is simply a descriptive adjective.)
- A noun followed by a number or a letter that indicates sequence. Exceptions: Do not capitalize the nouns *line, note, page, paragraph, size, step, and verse.*
  - – Article 2
  - – Figure 6
  - – Table 4

V. Figures and Tables

For conference publications such as this, the format for figures and tables is included in the instructions for preparing manuscripts for APEC 2004. Included is a downloadable sample manuscript, *Preparation of Paper in Two-Column Format for Conference Proceedings Sponsored by IEEE* [9]. The link directly to the sample manuscript is:

http://www.ieee.org/organizations/pubs/confpub/auxfiles/sample_manuscript.pdf

Table captions are centered at the top of the table, while figures captions are centered below the figures. Avoid placing a table or figure before it is mentioned in the text. Use the abbreviation "Fig. 1" when referring to it in the text, but spell out Figure 1 in the caption "Figure 1. Magnetizing current as a function of supply voltage." The IEEE style is to use a reduced font size for the figure caption. The IEEE style for table captions is to use small caps and roman numerals.

TABLE I
TEST PARAMETERS FOR BOARD-MOUNTED POWER SUPPLIES

VI. Equations

Number equations consecutively with equation numbers in parenthesis flush with the right margin, as in (1). Use parentheses to avoid ambiguities in denominators. Punctuate equations with commas or periods when they are part of a sentence, as in

$$a + b = c/(d + e). \quad (1)$$

When referring to the equation in a sentence, simply use (1), except at the beginning of a sentence: "Equation (1) is…"

VII. Some Common Mistakes [9]

The word "data" is plural, not singular, and the pronunciation is with a long "a" as in "April." A parenthetical statement at the end of a sentence is punctuated outside of the closing parenthesis (like this). (A parenthetical *sentence* is punctuated like this.) Be aware of the different meanings of the homophones "affect" and "effect," "complement" and "compliment," "discrete" and "discreet," "principal" and "principle." Do not confuse "imply" and "infer." (The person making the statement implies; the listener or reader infers.)

The prefix "non" is not a word; it should be joined to the word it modifies, usually without a hyphen, as "nonisolated." There is no period after the "et" in the Latin abbreviation "et al." The abbreviation "i.e." means "that is," and the abbreviation "e.g." means "for example." An excellent style manual for science writers is [10].

The most common mistakes seen in today's technical writing occur in product advertisements, as clearly observed in almost any trade magazine. Most of the designers of these display advertisements have never read a paper like this, nor are they aware of the listed references. It is up to the individuals and firms who hire them to insist on good technical form. Only by example and insistence on excellence can the battle be won.

References

[1] *ANSI/IEEE Std 260.1-1993, American National Standard Letter Symbols for Units of Measurement (SI Units, Customary Inch-Pound Units, and Certain Other Units)*, New York: The Institute of Electrical and Electronics Engineers, 1993.

[2] *IEEE Std 100-1996, The IEEE Standard Dictionary of Electrical and Electronic Terms*, New York: The Institute of Electrical and Electronics Engineers, 1996.

[3] *Webster's II New College Dictionary*, Boston: Houghton Mifflin Company, 1999.

[4] William Strunk, Jr., and E. B. White, *Elements of Style*, 3rd ed., New York: McMillan Publishing Co., 1979.

[5] William A. Sabin, *The Gregg Reference Manual*, 9th ed., New York: Glencoe McGraw-Hill, 2001.

[6] Michael Alley, Leslie Crowley, Jeff Donnell, Christene Moore, "Writing Guidelines for Engineering and Science Students," *http://filebox.vt.edu/eng/mech/writing*, Virginia Tech, U. of Illinois at Urbana-Champaign, Georgia Tech, U. of Texas at Austin (locations of the authors, respectively), 2002.

[7] Barry N. Taylor and Peter J. Mohr, "*NIST Reference on Constants, Units, and Uncertainty*," *http://physics.nist.gov/cuu/index.html*, National Institute of Standards and Technology, 2000.

[8] Ronald N. Standler, "Technical Writing," *http://www.rbs0.com/tw.htm*, Concord, NH, 2000.

[9] *Preparation of Paper in Two-Column Format for Conference Proceedings Sponsored by IEEE,* available on the IEEE Web site.at: http://www.ieee.org/organizations/pubs/confpub/auxfiles/sample_manuscript.pdf

[10] M.Young, *The Technical Writer's Handbook.* Mill Valley, CA: University Science, 1989.

APPENDIX

TABLE I
SI BASE UNITS

Unit	Symbol	Physical Quantity
meter	m	length
kilogram	kg	mass
second	s	time
ampere	A	electric current
kelvin	K	thermodynamic temperature
mole	mol	amount of substance
candela	cd	luminous intensity

For historical reasons, although the SI unit of mass is the kilogram (kg), the SI prefixes are attached to the gram (g). Thus, use milligram (mg), *not* microkilogram (μkg).

TABLE II
SI DERIVED UNITS WITH SPECIAL NAMES AND SYMBOLS

Quantity	Name	Symbol
electric capacitance	farad	F
electric charge	coulomb	C
electric conductance	siemens	S
electric inductance	henry	H
electric potential difference	volt	V
electric resistance	ohm	Ω
energy, work, quantity of heat	joule	J
force	newton	N
frequency (of a periodic phenomenon)	hertz	Hz
illuminance	lux	Lx
luminous flux	lumen	Lm
magnetic flux	weber	Wb
magnetic flux density	tesla	T
power, radiant flux	watt	W
pressure, stress	pascal	Pa

TABLE III
SI PREFIXES

Multiplication Factor	Prefix	Symbol
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3} = 1000	kilo	k
10^{2} = 100	hector	h
10^{1} = 10	deka	da
10^{-1} = 0.1	deci	d
10^{-2} = 0.01	centi	c
10^{-3} = 0.001	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p

A Brief Writing Guide

This is a brief guide for technical writing. It is based on the IEEE Dictionary (IEEE Std 100-1996), recognized world-wide, and other references: Standard for Use of the International System of Units (SI): The Modern Metric System (ANSI/IEEE Std SI 10-1997), American National Standard Letter Symbols for Units of Measurement (ANSI/IEEE Std. 260.1-1993), the IEEE Standards Style Manual, available on the IEEE web site, ieee.org, and The Gregg Reference Manual, Ninth Edition. Please help to make your company a leader in clean, concise documentation that complies with the international standards.

Correct	**Incorrect**
10 mV, 56 mm, 5 cm ±1 mm, 4.7 uF, 0.22 ohm. Always separate the value from the unit.	10mV, 56mm, 5cm+1mm, 4.7uF, .22ohm.
10 kilowatts, 10 watts, 10 kW, 10 W Capitalize the symbol, not the unit.	10 kiloWatts, 10 Watts, 10KW, 10Kw, 10w
The rise time is 10 ms. Symbol for seconds is s. (S is for siemens).	The rise time is 10 mS (or mSec, or msec).
Ac-dc converters are more popular than dc-dc. Use lower case and a hyphen. Capitalize at the beginning of a sentence.	AC/DC converters…
Ac-Dc Converters for Industrial Applications Title case is used in the title of articles, books. Sometimes it is also used in tables.	AC-DC Converters…
AC-DC HANDBOOK FOR SALE This is the "all caps" case. Hyphen is still used.	AC/DC HANDBOOK FOR SALE
The output is 10 Vac (or V ac, or volts ac). It is common to combine V and ac without a space.	The output is 10V ac (or 10 VAC)
FETs and ICs are used in modern converters. No apostrophe for plural (unless the singular already ends in s).	FET's and IC's are used…
The FET's gate drive is inadequate. Use 's for singular possessive.	The FETs gate drive is inadequate.
The FETs' gate drives are inadequate. Use s' for plural possessive.	The FETs' gate drive is inadequate.
It's unusual that its output ripple is high. It's is a contraction for it is. Use its for possessive.	Its unusual that it's output ripple is high.
The output is 10 Vrms (or 10 V rms). Rms is the proper abbreviation for root-mean-square.	The output is 10VRMS or 10 VRMS
The bus voltage is 15 volts. Correct spelling is bus, not buss.	The buss voltage is 15 volts.
The Web site is accessible on the Internet. Web and Internet are capitalized.	The website is on the internet.

Don't forget to use your spell checker!

Units, Symbols and Style Guide for Power Electronics Documents

This document is intended as a guide for writers of specifications, catalogs, application notes and correspondence in power electronics. It is derived from the current international standard, ANSI/IEEE Std 260.1-1993, used by the electronics industry world-wide when writing in English. The standard was prepared by the Standards Coordinating Committees of the following societies of the IEEE: Circuits and Devices, Communications Technology, Computer, Electromagnetics and Radiation, Energy and Power, Industrial Applications, and Signals and Applications. The initial section, *Style*, was derived from the IEEE Standards Style Manual.

The Power Sources Manufacturer's Association has prepared this guide in hope that it will lead to more uniform documentation and correspondence in the power electronics industry. This will enhance communication between vendors, customers and all other related businesses. Clearer communication will reduce the cost of doing business and benefit the industry in its entirety.

Style

Throughout this guide, square brackets [ ] will be used for examples of the topic.

Separation of quantity and unit --- In the expression for a quantity, leave a space between the numerical value and the unit symbol. [1 V, not 1V]

Abbreviations and acronyms --- Technical abbreviations and acronyms should be used to save time and space, but only if their meaning is unquestionably clear to the reader. The first use shall be spelled out, followed by the abbreviation or acronym itself in parentheses. Exceptions to this are approved Systeme International (SI) units. [The power factor correction (PFC) section is 95% efficient.]

Hyphenation --- In most cases, compound adjectives should be hyphenated. Exceptions can be made when strong preferences exist. [Switched-mode power supplies are generally more efficient than linear power supplies.]

Capitalization --- The initial letter shall be capitalized in:

Clause, subclause and annex headings in documents [1. Introduction, 2. Scope, 3.6 Schedule]
Specific cross-references in text [e.g., Table 1, Figure 12, Note 2, Equation (3)]
Captions for figures and tables [Figure 3. Voltage waveform under full-load conditions.]
Column and line headings in tables [Load current, Ripple, Spikes]
Numbered list entries, as in a column of accessories or features

Units

Leading zeros --- For quantities less than 1, place a zero in front of the decimal [0.1 μF]

Numerals --- Arabic numerals shall be used for all units of measure, time, and quantity. In general text, numbers of less than 10 shall be spelled out, except before a unit of measurement. [Five power supplies were tested, and in all cases the peak-to-peak output ripple was less than 5 mV.]

Tolerances --- If tolerances are provided, the unit shall be given with both the basic value and the tolerance. [150 m $\pm$5 mm]

Ranges --- Except in text, ranges may be written with a dash and without repeating the unit. [115-125 V] Text and dashed representations of ranges shall not be combined ["from 25 V to 50 V," not "from 25 V-50 V"]

Metric system --- In 1995, the IEEE implemented a new metric policy (IEEE Policy 9.20), which calls for measured and calculated values of quantities to be expressed in metric (SI) units in IEEE publications.

Letter symbols vs. abbreviations --- For expressing the units in which quantities are measured, letter symbols are preferred to abbreviations. Letter symbols are independent of language; abbreviations are not. [A, not amp]

Quantity symbols are usually a single letter, and are expressed in italic type.

A	area
I	current
x, y, z	Cartesian coordinates
i, j, k, n	indexes
f(x)	function of *x*

Unit symbols are used in place of the name of a unit and are printed in roman (upright) type.

cm	centimeter
e	base of natural logarithms
sin *x*	sine of *x*
$J_2(z)$, $J_n(z)$	Bessel functions
d*x*	differential of *x*

Subscripts and superscripts are governed by the above principles. Those that are letter symbols for quantities or for indexes are printed in italic type, while all others are printed in roman type.

I_o, V_i	Output current, input voltage
x_{av}	Average value of x

Mathematical expressions with numerator and denominator terms are to be unambiguous. Do not use sequential slashes. [*(a/b)/c), not a/b/c*]

SI prefixes are as follows.

Multiple	SI prefix	Symbol	Multiple	SI prefix	Symbol
10^{15}	peta	P	10^{-1}	deci	d
10^{12}	tera	T	10^{-2}	centi	c
10^{9}	giga	G	10^{-3}	milli	m
10^{6}	mega	M	10^{-6}	micro	μ
10^{3}	kilo	k	10^{-9}	nano	n
10^{2}	hecto	h	10^{-12}	pico	p
10	deca	da	10^{-15}	femto	f

Symbols

Unit symbols useful in power electronics are as follows:

Unit	Symbol	Notes
ampere	A	SI unit of electric current
ampere (turn)	A	SI unit of magnetomotive force
ampere-hour	Ah	Also A·h
ampere per meter	A/m	SI unit of magnetic ield strength
coulomb	C	SI unit of electric charge
degree Celsius	°C	SI unit of Celsius temperature
farad	F	SI unit of capacitance
henry	H	SI unit of inductance
hertz	Hz	SI unit of frequency
joule	J	SI unit of energy, work, and quantity of heat
kilogram	kg	SI unit of mass
newton	N	SI unit of force
ohm	Ω	
second	s	SI unit of time
siemens	S	SI unit of conductance (Ω^{-1})
tesla	T	SI unit of magnetic flux density
var	var	IEC name and symbol for the SI unit of reactive power
volt	V	SI unit of voltage
volt per meter	V/m	SI unit of field strength
voltampere	VA	IEC name and symbol for the SI unit of apparent power
watt	W	SI unit of power
watt per meter kelvin	W/(m·K)	SI unit of thermal conductivity
watthour	Wh	
weber	Wb	SI unit of magnetic flux Wb Δ V·s

Unit	Symbol
kilohertz	kHz
kilohm	kΩ
kilovar	kvar
kilovolt	kV
kilovoltampere	kVA
kilowatt	kW
kilowatthour	kWh
liter	L
liter per second	L/s
megahertz	MHz
megohm	MΩ
microsecond	μs
millisecond	ms
millivolt	mV
minute (time)	min
nanofarad	nF
nanosecond	ns
picofarad	pF

Note that names of units are not capitalized.

Rev. 2 Comments welcomed.