

Quantities, Units, Letter Symbols, and Abbreviations

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In order to communicate with their readers, authors must define the quantities, units, letter symbols, and abbreviations that they use. Rules and many examples are given to help authors to use understandable and standard forms. Relevant U.S. and international standards are cited

INTRODUCTION: For brevity, authors use abbreviations and letter symbols in writing. These abbreviations and letter symbols frequently impair communications with the general readers who usually do not know the author's "obvious" conventions. They may even retard communication among specialists in a field.

Observing the following rules helps ensure communications between authors and their readers:

1) Define every abbreviation or symbol the first time it appears. *Wrong:* "f of the vfo was 60 Hz to 80 Hz." *Right:* "The frequency *f* of the variable frequency oscillator (vfo) was 60 hertz [Hz] to 80 Hz."

2) State quantity names directly, do not count on the unit name to imply the quantity. *Wrong:* "The amplifier had 10 watts." *Right:* "The amplifier power output was 10 watts."

3) Add modifiers to the *quantities*, not to the *units*. *Wrong:* "The power was 10 watts peak." *Right:* "The peak power was 10 watts."

4) State the reference quantity for each kind of level when the level is introduced. Letters added to the decibel ("dB appendages") intended for clarification are neither necessary nor allowed in *Journal* publications. *Wrong:* "Amplifier output power level was +10 dBm." *Right:* "Amplifier output power level re 1 milliwatt was +10 dB."

These rules are in accordance with the standards of the American National Standards Institute (ANSI), the International Organization for Standardization (ISO), and the International Electrotechnical Commission (IEC). The standards of all these organizations are available from your national standards organization. A free catalog of ANSI, ISO, and IEC standards is available from ANSI, 1430 Broadway, New York, NY 10018, USA.

The various conventions are explained in this paper, examples are given, and the relevant standards are cited.

QUANTITIES

A *physical quantity* is described by a *measure* and a *measurement unit*. For example, "The amplifier output power (the physical quantity) was 10 (the measure) watts (the unit)." (The measure is also called the *numerical value*.)

Popular writers often confuse the *unit* with the *quantity*; they write the "wattage" of a device where in fact they mean the "power."

This style of usage also creeps into technical writing. *Journal* authors should always be particularly careful to define clearly each quantity being discussed. Do not rely on the units to identify the quantities. This is not just an academic problem: most units are associated with more

than one quantity. For instance, the ampere is the unit for electrical current, and it is also the unit for magnetic potential difference and for magnetomotive force—three very different quantities. Literally tens of other similar examples can be found. In fact, it would probably be difficult to find any unit which is used with only one quantity.

Do not, for instance, tell us that “the tape is 6.3 mm”: We will return the manuscript with a question, “in what direction?” Say “the tape width is 6.3 mm” if that is what you mean. Similarly, do not say “the amplifier impedance is 600 ohms,” for we must ask “which impedance—source? input? output? or load?”

Some quantities are ratios of two other quantities; for instance, speed is distance per unit time. The unit will therefore also be a ratio of two other units; for speed, the meter per second. In these quantities that are ratios of other quantities, avoid the meaningless mixture of quantity and unit such as “distance per second” or “meter per unit time”—these are neither quantities nor units. A common example of this mixture in electronics is the expression “noise power per hertz”: the quantity is “noise power per unit bandwidth,” and the unit is “watt per hertz.”

ANSI Y10.19-1969, “Letter Symbols for Units in Science and Technology,” Sec. 7, tells us that “attachment of letters to a *unit symbol* as a means of giving information about the *quantity* under consideration is incorrect. Thus MWe for ‘megawatts of electrical power’ and Vac for ‘volts, ac’ are not acceptable.” On the other hand, clarifying letters may be added to *quantity symbols*; for instance, P_e for electrical power, or U_{ac} for ac voltage.¹

The following excerpt from ISO 31/0-1974, “General Principles Concerning Quantities, Units and Symbols,” Sec. B.1.1, gives further details about the concepts of physical quantities, units, and numerical values:

“*Physical quantities* are concepts used for qualitative and quantitative descriptions of physical phenomena. Such quantities may be classified into categories, each category containing only quantities which are mutually comparable. If one of the quantities in such a category is chosen as a reference quantity, called the *unit*, any other quantity in this category can be expressed as a product of this unit and a number, called the *numerical value* of the quantity.

“For a quantity symbolized by A , this relationship may be expressed in the form

$$A = \{A\} \cdot [A]$$

where $[A]$ is here used to symbolize the unit chosen for the quantity A , and $\{A\}$ to symbolize the numerical value of the quantity A when expressed in the unit $[A]$.

“If the quantity A is expressed in another unit, $[A]'$, which is k times as large as $[A]$ (i.e. $[A]' = k [A]$), then the new numerical value, $\{A\}'$, becomes k times as small as $\{A\}$ (i.e. $\{A\}' = \{A\}/k$). The product $\{A\} \cdot [A]$ equals the

¹ American writers usually use the letter V for the quantity voltage, and V for the unit volts. In order to distinguish the quantity symbol from the unit symbol, we have here used U for the quantity voltage. U is the ANSI reserve symbol; it is the IEC and ISO chief symbol.

product $\{A\}' \cdot [A]'$, i.e. the quantity A itself is independent of the choice of unit.

“*Example*: The wavelength of one of the yellow sodium lines is

$$\lambda = 5896 \text{ \AA}.$$

“Changing the unit $[\lambda]$ for the wavelength from the ångström to the metre (which is 10^{10} times larger) leads to

$$\lambda = 5896 \text{ \AA} = 5896 \times (10^{-10} \text{ m}) = (5896 \times 10^{-10}) \text{ m}.$$

Thus the numerical value $\{\lambda\}$ of the quantity λ is 5896 when expressed in ångströms and 5896×10^{-10} when expressed in metres.

“*Remark on notation for numerical values*: It is essential to distinguish between the quantity itself and the numerical value of the quantity expressed in a particular unit. The numerical value of a quantity expressed in a particular unit could be indicated by placing curly brackets around the quantity symbol and using the unit symbol as a subscript. . . . It is often convenient, instead of using the subscript notation, to write the numerical value explicitly as the ratio of the quantity to the unit; this applies in particular to headings of columns in tables, and to the coordinates in graphs.

“*Example*:

$$\frac{\lambda}{\text{\AA}} = 5896 \text{ or } \lambda/\text{\AA} = 5896.”$$

In this latter application, the use of the square bracket around the unit is especially recommended by the *Journal* to avoid mistaking the unit for a quantity. Thus, in the examples above, $\lambda/[\text{\AA}] = 5896$.

Remember that most *Journal* readers come to your paper with only a general operational or engineering knowledge of your specialty. They will not be able to fill in the missing quantities which are so “obvious” to you, and they may miss your point, perhaps even drawing the reverse conclusions from those you intended.

Keep this rule in mind: If you properly name the *quantities*, you will never need to “clarify” the *units*. For example, if you say “rms current,” you will not be tempted to use the incorrect “amperes rms.” In other words, if you ever think it is necessary to modify or clarify a *unit*, you can be sure that you have not properly named the *quantity*.

ABBREVIATIONS

Abbreviations are conventional representations of words or names in a particular language, and they are therefore often different in different languages. Abbreviations are to be used only where necessary to save time and space. When a long word or phrase is needed frequently in an article, it may be replaced by an abbreviation. *Every* abbreviation not given in the AES “Author’s Guide” must be explained the first time it is used; for example, “variable frequency oscillator (vfo).” Abbreviations should not be used in mathematical formulas.

Journal authors finding it necessary to use abbreviations should use those standardized in ANSI Y1.1-1972, “Ab-

abbreviations for Use on Drawings and in Text." Use the letter symbol rather than the abbreviation in those cases where ANSI Y1.1-1972 gives both.

LETTER SYMBOLS FOR QUANTITIES AND UNITS

Letter symbols for quantities and units, as opposed to their abbreviations, represent the quantities or units (not their names), and are therefore independent of the particular language. Because of this the use of letter symbols for quantities and units is preferred over the use of abbreviations. For instance, the abbreviation for ampere is "amp," and its letter symbol is "A." In mathematical formulas, the letter symbols must be used, not the abbreviations.

Journal authors should use the letter symbols standardized in the following documents:

- 1) "Letter Symbols for Quantities Used in Electrical Science and Electrical Engineering," ANSI Y10.5-1968;
- 2) "Letter Symbols for Units Used in Science and Technology," ANSI Y10.19-1969;
- 3) the conventions standardized in the "Glossary of Terms Concerning Letter Symbols," ANSI Y10.1-1972.

The quantity and unit symbols, and conventions, internationally standardized by ISO and IEC are essentially identical to each other and to the corresponding ANSI standards, and are generally acceptable for *Journal* publication. The standards are ISO 31, "Quantities, Units, and Symbols" (12 parts, various dates); ISO 1000-1973, "SI Units and Recommendations for the Use of Their Multiples and of Certain Other Units"; and IEC No. 27, "Letter Symbols to be Used in Electrotechnology," "Part 1, 1971, General," "Part 2, 1972, Telecommunications and Electronics," and "Part 3, 1974, Logarithmic Quantities and Units."

Every symbol without exception must be explained the first time it appears; for example, "the amplifier average output power $P_{o\text{ av}}$ was 10 watts [W]."

A convenient summary of the ANSI standards on symbols is given in the "Standard Handbook for Electrical Engineers," 10th edition, D. G. Fink and J. M. Carroll, Eds., McGraw-Hill, New York, 1968. See Section 1, "Quantities, Units, and Conversion Factors." Many libraries have this handbook.

Manuscripts not conforming to these standards will be conformed by the *Journal* editors, or returned to the author for the required changes.

Special Note on Levels and Decibels

Quantities "expressed in decibels" are particularly subject to being named not by their quantity names but by their units plus "explaining letters" (sometimes called "dB appendages"). Thus we are all too often told that the level is 10 dB, or 10 dBm, or 10 dBV, etc. We are left to guess for ourselves whether it is an input level or an output level; whether it is a power level or a voltage level; what the reference quantity is, etc. At no time should the "decibel appendage" be relied upon to explain the kind of level.

This matter has been reviewed previously in the Standards Column of the *Journal*: "Levels and Decibels," *J.*

Audio Eng. Soc., vol. 19, p. 524 (June 1971); in a letter to the Editor by R. W. Young, "Decibel, a Unit of Level," *J. Audio Eng. Soc.*, vol. 19, pp. 512, 514 (June 1971); and in the review by J. G. McKnight of ANSI S1.8, "Preferred Reference Quantities for Acoustical Levels," *J. Audio Eng. Soc.*, vol. 19, p. 804 (Oct. 1971). Authors and standards committees are still struggling with the "decibel problem." The most recent and authoritative publication is IEC No. 27-3, "Logarithmic Quantities and Units," first edition, 1974.

The arguments against the use of "decibel appendages" are as follows:

1) ANSI Y10.19, Sec. 7, specifically prohibits the "attachment of letters to a unit symbol as a means of giving information about the *quantity* under consideration . . ."

2) "Decibel appendages" are only necessary when the author has failed to identify properly the quantity and the reference quantity. When the quantity and the reference quantity are specifically stated, there is neither ambiguity nor any need for any "decibel appendage."

3) The modification (in preparation) for IEC Publication 268-2, Sec. 3.2, reads (in part):

"Voltage Levels

The voltage level L_U in decibels is twenty times the logarithm to the base ten of the ratio of the voltage under consideration U in volts, to the reference voltage U_{ref} in volts:

$$L_U \text{ re } U_{\text{ref}} = 20 \log (U/U_{\text{ref}}) \text{ [dB].}$$

The reference voltage shall always be indicated."

The AES *Journal* Publication Policy Committee has considered these arguments and concluded that it shall be the policy of the AES *Journal* not to permit the use of "dB appendages" in published articles. Each author shall name the quantities and reference quantities for all levels which he uses. Where a few levels are mentioned in a paper, the quantity symbol or abbreviation for the level shall be explained in detail and the reference quantity for the level shall be stated at its first mention.

Example with Quantity Abbreviation: At first appearance: "The sound pressure level (SPL) re 20 μPa was +20 dB." At later appearance: "The SPL was increased to +50 dB."

Example with Quantity Symbol: At first appearance: "The sound pressure level L_p re 20 μPa was +20 dB." At later appearance: " L_p was increased to +50 dB."

When many quantities and reference quantities are to be used in a single paper, the author should provide a table giving all the quantities, their symbols and/or abbreviations, brief definitions if needed, and the reference quantities.

SUMMARY

Specify each quantity you use by its complete name; do not rely on the reader to divine the *quantity* from the *unit* given in a measurement. Do not use the unit name for the quantity name.

Follow these same rules with levels and decibels. When a level is introduced, state the quantity name and the reference quantity. "dB appendages" are not needed and are not allowed in the *Journal*.