Quantities, Units, Letter Symbols, and Abbreviations[1]

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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 international and U.S. standards are cited.

0 INTRODUCTION:

For brevity, authors use abbreviations and letter symbols in writing. These abbreviations and letter symbols sometimes 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. *For example:* "The frequency *f* of the variable frequency oscillator (vfo) was 60 hertz [Hz] to 80 Hz," *rather than* "*f* of the vfo was 60 Hz to 80 Hz."

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

3) Add modifiers to the *quantities*, not to the *units*. *For example*: "The peak power was 10 watts," *rather than*: "The power was 10 watts peak."

4) When levels in decibels are used, 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 not necessary, and are strongly discouraged in *Journal* publications. *For example*: "Amplifier output power level re 1 milliwatt was +10 dB," *rather than*: "Amplifier output power level was +10 dBm."

These rules are in accordance with the standards of the International Standards Organization (ISO) [1], and the International Electrotechnical Commission (IEC) [2]. The standards of these organizations are available expensively directly from them or from your national standards organization – but you probably cannot afford to buy them for occasional use in audio engineering.

The AES has prepared a review of the System of International Units (SI Units, SI metric) standards in general [3], available free on line, with references to free downloadable summaries of many of the standards.

The International Committee for Weights and Measures (BIPM in French) has published a rather academic brochure that describes their work and the resulting SI Units, and presents and defines the SI (System of International Units) [4].

As a practical guide, the US National Institute of Standards and Technology (NIST, nee NBS) has published a "Guide for the Use of the International System of Units (SI)" [5], that excerpts or summarizes the ISO and IEC Standards, and is available for free download.

That guide contains a separately-available "Check List for Reviewing Manuscripts" [6] which is very useful for checking conformance to SI Unit rules and style conventions.

The various SI conventions are explained in the present paper, examples relevant to audio engineering are given, and the relevant standards are cited.

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.

1 QUANTITIES and UNITS

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

1.1 Conflating Quantity and Unit

Popular writers often conflate 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 physical 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.

[1] Revised in 2013-07. This document updates and replaces the 1976 Journal paper of the same name..

Do not, for instance, say that "the tape is 6.3 mm", because that begs the 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," because that begs the question "which impedance— source? input? output? or load?"

Some quantities are ratios of two other quantities. For instance, speed is distance divided by 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 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 divided by bandwidth," and the unit is "watt per hertz."

1.2 Attachments to Units

Engineers sometimes attach a letter to a unit symbol to describe the quantity – for instance "Mwe" to designate "megawatts of electrical power". But modern practice is 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 $\boldsymbol{U}_{\mathrm{ac}}$ for ac voltage.[2]

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*.

1.3 Some General Principles

The following excerpt from ISO 31-0 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 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

$\lambda = 5896$ Å.

"Changing the unit for the wavelength λ from the ångström to the metre (which is 10^{10} times larger) leads to

$\lambda = 5896$ Å $= 5896 \times (10^{-10}$ m$) = (5896 \times 10^{-10})$ 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:*

$$\frac{\lambda}{\text{Å}} = 5896, \text{ or } \lambda/\text{Å} = 5896."$$

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, $\lambda/[\text{Å}] = 5896$.

2 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 must be explained the first time it is used; for example, "variable frequency oscillator (VFO)." Abbreviations should not be used in mathematical formulas.

The list of abbreviations is endless, changing with the subject under consideration. *Journal* authors finding it necessary to use abbreviations should first check the "Appendix II, Some Common Acronyms and Abbreviations" in the IEEE "Information for Authors" [7].

[2] 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.

3 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 quantity and unit symbols and conventions internationally standardized by ISO [8], [9] and IEC [10]. They are essentially identical to each other and to the corresponding ANSI standards.

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

Note that *quantity* symbols (like P for power) are always to be printed in italics, whereas *prefix symbols and unit symbols* (like W for watt) are always to be printed in roman (upright) type.

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

4 SPECIAL NOTE ON LEVELS AND DECIBELS

Many engineers treat the decibel as a quantity, writing “dB = 10 log P_2/P_1", having no unit at all. Actually, modern standard usage is that the quantity “logarithm of a ratio” is called a “level”, and the unit of level is the decibel. This matter has been reviewed previously in the Standards Column of the *Journal* [11], [12], [13], and is the subject of the international standard IEC 27-3, “Logarithmic Quantities and Units” [10].

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 usually 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 a “decibel appendage” be relied upon to explain the kind of level.

The AES Standards Committee has considered the “level and decibel problem”, and we recommend that you get and read the download of AES-R2, “Notations for expressing levels” [14].

The AES *Journal* Publication Policy Committee has considered these arguments and concluded that it shall be the policy of the AES *Journal* to strongly discourage the use of “dB appendages” in published articles. Each author should name the quantities and reference quantifies for all levels which he uses. Where a few levels are mentioned in a paper, the quantity symbol or abbreviation for the level should be explained in detail and the reference quantity for the level should 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.

5 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 instance, decibel) for the quantity name (level). 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 strongly discouraged in the *Journal*.

6 REFERENCES

[1] International Standards Organization, http://www.iso.org/iso/en/prods-services/ISOstore/store.html .

[2] International Electrotechnical Commission, http://webstore.iec.ch/

[3] G. Franklin Montgomery, “Metric Review”, originally in the AES Journal in 1984, now available without charge, with updated references, at http://www.aes.org/journal/pdfs/metricreviewupdated.pdf .

[4] BIPM, “The International System of Units (SI)”, now available without charge at www.bipm.org/en/si/si_brochure/ .

[5] B. N. Taylor, “Guide for the Use of the International System of Units (SI)”, NIST Spec. Publ. 811. Available for free download at physics.nist.gov/cuu/pdf/sp811.pdf

[6] “NIST SI Unit rules and style conventions: a check list for reviewing manuscripts” physics.nist.gov/cuu/Units/checklist.html

[7] IEEE “Information for Authors”, Appendix II, p A9, “Some Common Acronyms and Abbreviations,” free download at http://www.ieee.org/documents/auinfo07.pdf see page 20 of the PDF.

[8] ISO 31-0...ISO 31-11, “Quantities, Units, and Symbols” (12 parts, various dates and prices). Now replaced by a joint ISO & IEC 80000-x series, parts 1 to 14. (The part numbers do not correspond at all with the older series.)

[9] ISO 1000-1973, “SI Units and Recommendations for the Use of Their Multiples and of Certain Other Units”

[10] IEC 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.”

[11] “Levels and Decibels,” *J. Audio Eng. Soc.*, vol. 19, p. 524 (1971 June)

[12] R. W. Young, “Decibel, a Unit of Level,” *J. Audio Eng. Soc.*, vol. 19, pp. 512, 514 (1971 June)

[13] J. G. McKnight, review of ANSI S1.8, “Preferred Reference Quantities for Acoustical Levels,” *J. Audio Eng. Soc.*, vol. 19, p. 804 (1971 Oct.)

[14] AES “Project report for articles on professional audio and for equipment specifications – Notations for expressing levels”, http://www.aes.org/publications/standards/ enter“AES-R2" into the “search” box .