Formatting Guidelines for Equations and Technical Content

Equations are essential elements of many technical documents and presentations. The mathematical expression of models, dependencies, patterns, and other conceptual relationships in the physical world forms the foundation and language of engineering and science. Just as there are many standards for expressing mathematical ideas that are second-nature to you by now (such as the multiplication, summation, and integration symbols), there are also standards for formatting and referencing equations in print. It is very likely that you will be incorporating equations into documentation throughout your career, so you should familiarize yourself with the relevant standards and begin using them now. Just as poor grammar and organization can frustrate a reader and lead them to suspect your professional competence, so can the careless presentation of equations lead to the same suspicion.

The items below cover some of the most important aspects of formatting and referencing equations and the use of values and units in documents. The information is not exhaustive since the purpose of this guide is only to highlight the fundamentals. More detailed information is available in high-quality references such as the *IEEE Editorial Style Manual* (available at the course Moodle site) and a wide variety of books on technical communication.

Equations, Equation Formatting, and Equation Referencing

1. Equations should be typeset using an equation editor provided by your word processing software. Built-in editors vary widely in quality, so if your favorite software has an inferior editor, you should consider generating equations using an online equation editor or obtaining third-party software that can be integrated into your word processor. A good equation editor should automatically incorporate many of the formatting standards listed below. As of November 2023, the equation editor included in Google Docs has many shortcomings; you should think twice before using it for important professional documents.

2. Variables should be italicized. Alphabetical subscripts should be italicized as well, but not numerical subscripts. Some style guides specify that a subscript that is a whole word or abbreviation of a word (such as “pk,” “in,” “out,” “end,” or “max”) should not be italicized. The latter practice does not seem to have a consistent standard, so you are free to use either practice in this course.

3. Numbers (digits 0 through 9) and numerical quantities (e.g., voltage values) in equations should not be italicized.

4. Function names or abbreviations, such as sin, cos, and exp, should not be italicized.

5. Vectors and matrices are formatted in a variety of ways, but a commonly accepted standard is to represent vector quantities in bold face and not italicized. Context and consistency are key; choose a system and stick to it, and explain it in the text.

6. Do not use an asterisk (*) to represent scalar or vector multiplication. Instead, express a product simply by writing the variables next to each other or, in more complicated expressions, by using parentheses. The asterisk is often used to represent other operations, such as convolution or complex conjugation, so its use to represent multiplication could cause confusion. Be careful when using a dot (·) to represent multiplication, since it could be confused with the vector dot product symbol. An exception to this rule applies when Matlab code (or that of other languages) is listed in the text. In that case, the language syntax should be retained. Also, dots can be used to clarify compound units (e.g., “the speed was 15 $\mathrm{m} \cdot \mathrm{s}^{-1}$”).

7. Add one line of horizontal space before and after each equation.

8. Equations should be centered horizontally on the page.

9. If the equation is numbered, right-justify the number on the same line as the equation. In many types of popular word-processing software, this requires the insertion of center and right tabs on the line. Equation numbers are usually placed in parentheses or, less commonly, in [square brackets].

10. Although equations can be (and frequently are) numbered, they should never have captions. Put all explanations of equations in the text, not in a caption. Citations to sources of equations should be embedded in the descriptive text as well.

11. References to equations in the text should be by number or position (e.g., "The equation below expresses…", "The result given by Equation (3) implies that…"). Equations should be explained in the body of the text. Do not assume that the equation can stand alone. The reader should not have to deduce on their own why the equation is there and what information it is supposed to convey.

12. When referring to equations by number, do not spell out the number. For example, use "Equation (1)" or "Eqn. (1)". If parentheses are placed around the equation numbers next to the equations, then parentheses should be used in the text references to the equations as well. The word "Equation" should be capitalized when used with a number to refer to a specific equation. A widely used standard does not use the word "Equation" at all. Instead, equations are referred to only by their numbers. For example, "The relationship expressed in (3) shows that…" In this example, "(3)" refers to Equation (3). In this style, parentheses or square brackets should be used around equation numbers. You may use the latter method, if you wish.

13. Calculations of numerical results obtained from formulas should be demonstrated explicitly by showing how appropriate numerical values were substituted into the equation. An example is given below. This serves several purposes. One is to save the reader from searching the text to find the values that were substituted. Another is to prevent any ambiguity or confusion over which particular values should be substituted for the various variables in the equation. A common example is the specification of AC voltages (peak-to-peak, peak, or rms?). Still another purpose is to clarify any required scaling (e.g., 200 μA in the equation below is expressed as 200×10^{-6}).

$$R_S = \frac{V_{DD}}{3I_D} = \frac{3.3}{3\left(200 \times 10^{-6}\right)} = 5.5\ \mathrm{k}\Omega$$

Values and Units

1. All numerical values should include units, and units should be represented using appropriate symbols, not spelled out. For example, use "50 Ω" instead of "50 ohms." Greek letters are rendered in Microsoft Word by typing the corresponding Latin letter and then changing its font to Symbol; capitalization is preserved. For example, the letter "w" in Symbol font is "ω," and "W" is "Ω." The volt unit is represented by a capital "V" (never lower-case) and the watt by a capital "W." If you spell out units, in most cases they should not be capitalized, even if they are derived from a person's name (e.g., "volt," "watt," and "farad").

2. Specify whether AC or other periodic voltages and currents are expressed as peak (pk), peak-to-peak (pp), or rms values, as applicable.

3. Pay attention to the number of significant digits in final calculated or measured values. Avoid using more digits than are justified.

4. Include a space between a value and its unit. For example, write “10 V,” not “10V.” This includes temperatures. Twenty degrees Celsius (an example of a rare capitalized unit, by the way) should be represented as 20 °C. The only common exception is the degree symbol when it is used to represent angles; in that case, there is no space between the value and the symbol (e.g., 120°). As for the percent symbol (%), English style guides usually state that there should be no space between the value and the symbol, but the International System of Units states the opposite. Thus, in this course the use of a space between a value and the % symbol is optional.

5. Keep values and their associated units (e.g., “3 mA”) on the same line; do not let them be separated by line breaks. This guideline also applies to figure references, table references, and equation references (e.g., “Figure 2,” “Table 1,” and “Equation (4)”). To prevent line breaks in Microsoft Word, hold down the Shift-Ctrl keys while typing the space or hyphen between the value and the unit.

6. Include a leading zero in fractional values expressed in decimal form. For example, use “0.01 V” instead of “.01 V.”

7. Do not italicize units (e.g., 3 *mA*). This often happens in equations because equation editors usually treat all alphabetical characters as variables, which are italicized by default. In Microsoft Word, if units are used in an equation, highlight the unit with the cursor, and set its style to “Text” in the equation editor.

8. The metric prefix “k” (for “kilo”) should be in lower case, not upper case. “Mega” is an upper-case “M;” “milli” is a lower-case “m;” “micro” is the lower-case, but not italicized, Greek letter “μ” (made by typing “m” and then changing its font to Symbol).

9. If the MΩ unit is spelled out, use “megohms,” not “megaohms.”

10. Use a hyphen in a value/unit combination only when it acts as an adjective and only when the unit is spelled out. For example, you should use a hyphen in the sentence “Most communications equipment is designed to have 50-ohm input and output impedances.” However, you should not use a hyphen in the sentence “Most communications equipment is designed to have input and output impedances of 50 ohms.” The difference is that “50-ohm” is used as an adjective that modifies the noun “impedances” in the first sentence. In the second sentence, the phrase “of 50 ohms” is a noun phrase. If unit symbols (Ω) had been used, which is usually preferred in technical writing, the hyphen would not have been necessary, even if “50 Ω” had been used as an adjective, although many style guides permit or even encourage the use of the hyphen in such situations. For more on these distinctions, see the “Writing unit symbols and the values of quantities” section of the Wikipedia page “International System of Units.” This topic is also discussed in the *IEEE Editorial Style Manual*.

Miscellaneous Technical Issues

1. Define all variables used in figures, equations, and the text that are not widely understood or obvious from context. For example, you should not assume that your reader knows what “v_{in}” means. On the other hand, π is universally understood to mean 3.141592654…

2. Do not use the same component labels for different devices in different circuits. For example, if you use R_1 and R_2 to represent the resistors in a voltage divider, do not label the resistors in a separate voltage divider as R_1 and R_2 as well. As another example, multiple input voltages should not all be labeled as v_{in}. Suggestion: use v_{in1}, v_{in2}, etc. instead.

3. Reactance values are real numbers, and impedances are complex. Therefore, reactance values should never contain a j (i.e., the square root of −1). For example, in the expression $Z = 300 - j200\ \Omega$, the reactance is $-200\ \Omega$, not $-j200\ \Omega$. Also, j should be italicized since it is a scalar variable.

4. Percentage error (not "percent error") is calculated using the formula

$$\% \text{ error} = \left(\frac{\text{measured value} - \text{reference value}}{\text{reference value}} \right) 100\%$$

   An easy way to check that you have the correct form is to remember that 105 is 5% higher than 100. The algebraic sign is important and should be retained; a positive error means that the measured value is above the reference, and a negative error means that the measured value is below.

5. Percentage error (not "percent error") is irrelevant when comparing a value to a *range* of typical values. For example, suppose that an op-amp datasheet specifies that the typical input offset voltage is 1 mV and the maximum is 5 mV. If you measure a value of 2 mV, your measurement is not "off" of the typical value (1 mV) by 100%. The measured value lies well within the range of expected values.