S2014, BME 101L: Applied Circuits Lab: Guidelines

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1 How to write up a lab

This document is a combination of advice from Kevin Karplus and Steve Petersen, who have slightly different hot buttons for what they care about. It is based on a handout prepared by Steve Petersen for EE 157, modified by Kevin Karplus.

Reports will emphasize experimental work and concisely summarize that work through an informal reporting style that expresses your individual grasp and understanding. These reports are engineering design reports, as you would write if hired as a consultant on an engineering project. They are **not** high-school chem-lab style proof that you successfully followed a cookbook procedure.

Because of space limitations in the lab and to improve learning in the lab, all labs will be done by pairs of students (unless there are an odd number of people in class, in which case we will have a singleton, not a triple). For each lab the pairing will be different, so that no one has an unfair advantage or disadvantage from consistently being paired with a more or less competent partner.

For each lab, the partners have to choose whether to turn in a joint report with both names on it as co-authors, or separate reports with one author each, but explicitly acknowledging in writing the work done by the other partner. Both partners should keep their own lab notebooks, as they may not have access to their partner's lab notebook later in the quarter.

Any student may redo any lab write-up (except the last one of the quarter), but those who get a "REDO" *must* redo them. Students who turned in a joint report may redo the write-ups individually or together, but once an individual report has been turned in, then joint reports are no longer possible. When redoing a lab report, turn in the old, commented-on report attached behind the new one.

Don't wait a long time before redoing reports—unless the lab work needs to be repeated, redone reports should be turned in within a week of getting back the commented-on report.

Warning: I have higher expectations for late or redone reports, so don't make only trivial changes and re-submit—your grade can go down. Make substantive changes that significantly improve the quality before resubmitting.

2 Audience

The instructor is **not** the audience for the lab report—indeed the professor is rarely the right audience for anything you write in college. You are not writing a textbook (providing chapters full of background) nor a graduate thesis (providing lots of background as well as huge amounts of new material), but a short design report for a busy engineering manager who is not intimately familiar with the problem you are solving or for an new engineer who will need to take over the project.

To get the level of detail right, imagine that you are writing to a fellow bioengineering student who has not yet taken this course or who is a few weeks behind in the course. You don't have to teach the course, but you do have to explain exactly what your design is and how you developed it.

You cannot assume that the reader of the report has read the assignment—the design report is a stand-alone document.

3 Length

There is no minimum nor maximum length requirement. The scope and depth of what you report on depends on what you were asked to do, learn, or become familiar with.

In the past, students have started the quarter writing far too little, not explaining how they did their design or measurements. By the end of the quarter, almost everyone was was getting the right level of detail.

4 Structure

Your report should start with a brief explanation of the problem to be solved, then explain how the problem was solved—what measurements were taken, what calculations were done, what design decisions were made, and what the final result was.

A report will normally consist of the following items:

- A cover sheet with the usual information (layout is up to you): the name and number of the lab (for example, "Lab 1: thermistors"); class (BME 101L); student's name; and date report was written (due date and instructors' names can also be provided). If you worked with a second student (as most will in this class), both names should appear on the cover. If you turn in separate reports, one name should be as author, the other should be listed as the lab partner.
- The report itself, consisting of
  - A statement of the problem.
  - Any pre-lab analysis and design that was done.
  - A statement of the solution to the problem. This will often include a block diagram showing how the problem is decomposed in subproblems.
  - Convincing evidence that the solution is a valid, even a good, solution to the original problem. This evidence will usually involve discussion of design constraints, possibly calculations, probably measurements, and almost certainly some citations to data sheets, application notes, web pages, or other sources of inspiration.
  - Schematics for any circuits that are made for the solution or for testing along the way. Lab reports with incorrect schematics will automatically get a "REDO". Incorrect schematics are simply not acceptable in this course.
  - Plots of any data collected, often with models fit to the data.

Reports must be organized, neat and legible; computer-generated typed work is expected. Each report should be complete, thorough, understandable, and literate.

Section headings should be descriptive, not generic. Someone picking up the report and reading just the title and section headings should have a fair idea what the report contains. If you use the same section headings in two different labs, your headings are too generic. This is not the *Journal of Molecular Biology* and we don't accept their belief that all articles must have exactly the same section headings in exactly the same order.

I prefer a style where description of techniques, results, and discussion all flow naturally and are not separated into widely different parts of the report. I realize that many biology journals favor or enforce a style in which Methods, Results, and Discussion are all separate sections (with Methods often tucked away at the end as an afterthought). Because this is a common style in biology papers, I don't deduct for it, but it really is much harder to read than a report that talks about the results of a test as soon as the test is described.

5 Math formulas

You will have a lot of math formulas in your reports, and common word-processing tools like MSWord do a terrible job of typesetting math.

I highly recommend learning to use LaTeX for producing your reports. There is a good tutorial (aimed at high-school students) at `http://www.artofproblemsolving.com/Wiki/index.php/LaTeX:About` On Mac OS 10, I installed just the small BasicTeX package `http://tug.org/mactex/morepackages.html`, but a lot of students prefer to have a GUI front end like TeXWorks, TexShop, or LaTeXiT.

Whatever tool you use, you will have to find a way to enter math formulas properly, as it is not a good idea to cut and paste formulas as images from web sites. The resulting images are often hard to read, even harder to edit, and more often than not use a different notation than the rest of your report.

It is not adequate to use just the name of a formula (like "Steinhart-Hart equation")—you must include the actual formula (like $\frac{1}{T} = A + B\ln(R) + C(\ln(R))^3$).

When you introduce a formula, you should explain what each variable is: T is temperature in °K, R is resistance in ohms at T, and A, B, and C are so-called Steinhart-Hart coefficients, which are used to fit the equation to the measured behavior of a thermistor.

6 Schematics, Graphs, and other Figures

Where appropriate, include well-drawn and labeled engineering schematics for each significant circuit investigated. This is not just the final design, but prototypes you rejected (and why they were rejected), and test circuitry you set up to understand or measure components.

Use good drafting practice when producing figures, graphs, drawings, or schematics and label them for easy reference. No picture, table, schematic, or graph should appear without a name (generally of the form "Figure 1" or "Table 3"), and none should appear without a reference to them **by name** in the main body of the writing. Space must be provided in the flow of your discussion for any tables or figures—do not collect figures and drawings in a single appendix at the end of the report. Ideally figures are on the same page as the discussion of them.

Schematics must be computer-generated, using a tool like the free web-based SchemeIt `http://www.digikey.com/schemeit`

Transcribe all relevant data from your engineering notes into your report. You do not need to provide tables of the 1000s of data points you collect—but you should graph them. Since you may be collecting 1000s of data points in one experiment, using a microprocessor, it will not be acceptable to hand-plot the data. You must use a computerized graphing tool (such as gnuplot, which is provided in the labs). Excel is not an acceptable graphing tool after elementary-school science fairs—learn to use one that works (there are 100s available, but gnuplot will be the one demonstrated in class). You will often need to fit non-linear models to your data, so make sure that the tool you choose can do that easily, and that you can use log scales for the axes.

A plot should always have a meaningful title and the axes should always be labeled. The axis labels should include the appropriate units (usually in square brackets: "thermistor resistance [ohms]" or "temperature [°C]".

Don't mix unrelated things or things with different units on the same plot (like resistance vs. temperature and voltage vs. temperature)—that practice just leads to confusion and hard-to-interpret graphs.

But do collect all *related* data into a single figure. For example, you may have collected current vs. voltage data for different voltage ranges in different experiments, but combining them into a single plot is useful, even if different measurement methods were used for low voltages and high voltages.

Screen shots don't work well in reports and are often completely unreadable. SchemeIt is capable of exporting both PDF and PNG formats. PDF is generally better for inclusion in a text document, and

PNG is better for blog posts and other web-only documents.

With gnuplot you can use a script like pdfscript:

```
set terminal pdf color
load 'script-name.gnuplot'
```

with the command

```
gnuplot < pdfscript > script-name.pdf
```

to produce pdf vector images that can be included in documents with no loss of resolution.

Including the gnuplot scripts you used as an appendix to your report is a good idea.

7 Citation

Cite any external work that you used (data sheets, text books, Wikipedia articles, ...). If you get a formula from a Wikipedia article, you must cite the article, giving the title, the URL, and the data you accessed the article as a minimum.

If you copy a figure, not only must you cite the article you copied from, but you must give explicit figure credit in the caption for the figure: "This image copied from ... ." If you modify a figure or base your figure on one that has been published elsewhere, you still need to give credit in the caption "This image adapted from ... ."

Provide *explicit written acknowledgment* of any human help you got. It's fine to get help, but claiming that work as your own (which is what failure to acknowledge is) is the definition of the most serious of academic sins: plagiarism. You will get charged with an academic integrity violation for failure to acknowledge help.

8 Random style and usage notes

The four "Cs" of technical writing are the adjectives Clear, Correct, Complete, and Concise. There is an obvious tension between completeness and conciseness, and a similar tension between clarity and correctness. You will have to leave out most textbook material and the details that would go into a thesis, but still have all the information that a manager would need to make a good decision and defend it to higher management.

Grading will be based on completeness, clarity, understanding, and justification of results.

Remember, you are reporting on something done in the past. Therefore, most of what you write will be expressed in the past tense. To aid you in resolving questions about tenses, the following summary should be helpful:

- Experimental results should always be given in the past tense.
- Things that are continuously true should generally be given in the present tense (like what parameters the data sheet claims).
- Discussions or remarks about the presentation of data should mainly be in the present tense.
- Suggestions for actions to take as a result of the study should generally be in the future tense.
- Discussions of results can be in both the present and past tenses, shifting back and forth from experimental results (past tense) to the conclusions and statements that are continuously true.

Use the correct prepositions for talking about voltage, current, or resistance. We have voltage *between* two nodes, or *across* a component. We have current *into* or *out of* a node, or *through* a component. We have the resistance or impedance *of* a component.

Be careful with your use of the subjunctive "would". In technical writing, this mood is generally only used for "contrary to fact" hypotheses, though it has other uses in general writing. For example, "the sound would be picked up by the microphone" implies that it was not picked up, because something was preventing it. I always want to see a reason: "the sound would be picked up, but there is an inch of lead keeping the microphone diaphragm from moving". Never is "would be" just a formal form of "was". If you don't know how to use "would" correctly, then never use it—that is safer than using it wrong and won't cramp your style much.

Don't use a colon between a verb and its object. The colon is normally used between a noun phrase and a restatement of the noun phrase. A common noun phrase before a colon is "the following"—consider the following: thing one, thing two, and thing three. This usage is so common that a lot of people try to put colons before every list, which is simply wrong. Note that having the list displayed as bullet points doesn't change any of the punctuation rules. There are no colons unless you are separating a noun phrase from its restatement.

OK: … include the following: a resistor, a capacitor, and a transistor.

No colon: … include a resistor, a capacitor, and a transistor.

"Data" is not calibrated—devices are. Data can be measured, recorded, or analyzed, and the result of all that can be the calibration of a device or system (though most often data is collected for some other purpose). Incidentally, I don't care whether you consider "data" to be a plural noun (plural of "datum") or a collective noun, which behaves like a singular noun in English—just be consistent.