Formal Laboratory Report Preparation Guidelines

Lab reports are the most frequent kind of documents written in engineering. The goal of the lab report is to document your findings and communicate their significance. A good lab report does more than presenting data; it demonstrates the writer's comprehension of the concepts behind the data. Merely recording the expected and observed results is not sufficient; you should also identify how and why differences occurred if any, explain how they affected your experiment, and show your understanding of the principles the experiment was designed to examine. Bear in mind that a format, however helpful, cannot replace clear thinking and organized writing. You still need to organize your ideas carefully and express them coherently.

The following outline is for your reference only. It describes what should be included in a typical report. The basic criterion is that someone who does not have any prior information about the experiment must be able to follow your experimental procedure. Furthermore, your report must convey all relevant observations and results. There is no pre-determined length for a report. However, the best report is the most concise one which also happens to be complete.

Title Page

The title page[1] needs to contain the name of the experiment, the names of lab partners, and the date the lab was performed and/or the date the report was submitted. Titles should be straightforward, informative (i.e., not "**Experiment 1**" but rather "**Experiment 1:** Spectral Analysis").

Abstract

The abstract summarizes four essential aspects of the report: the purpose of the experiment (sometimes expressed as the purpose of the report), key findings, significance and major conclusions. The abstract often includes also a brief reference to theory or methodology. The information should clearly enable readers to decide whether they need to read your whole report. The abstract should be one paragraph of 100–200 words.

Introduction

The Introduction is more narrowly focussed than the abstract. It states the objective(s) of the experiment and provides the reader with background to the experiment. State the topic of your report clearly and concisely, in one or two sentences.

A good introduction also provides whatever background theory, or formulas the reader needs to know. Usually, an instructor does not want you to repeat the *Lab Manual/documents* or the course reference text, but to show your own comprehension of the problem. If the amount of introductory material seems to be a lot, consider adding subheadings such as: *Theoretical Principles or Background*.

[1] This title page is different than the *Standard Cover Page* required for all work submitted by students in the Department of Electrical and Computer Engineering. The *Standard Cover Page* is available from the **Laboratory** menu item on the ELE 635 course page on BlackBoard. All students who authored the report must sign the *standard cover page*.

Note on Verb Tense: Introductions often create difficulties for students who struggle with keeping verb tenses straight. These two points should help you navigate the introduction:

- The experiment is already finished. Use the past tense when talking about the experiment: "*The objective of the experiment was ...* "
- The report, the theory and permanent equipment still exist; therefore, these get the present tense: "*The purpose of this report is ...* ", "*Sampling Theorem is ...* ", "*The spectrum analyzer produces graphs ...* ".

Methods and Equipment

This section can usually be a simple list, but make sure it is accurate and complete. In some cases, you can simply direct the reader to a *Lab Manual/documents* or standard procedure: "*Equipment was set up as in ELE 635 Laboratory Manual.*"

Experimental Procedure

Experimental procedure describes the process in chronological order. Using clear paragraph structure, explain all steps in the order they actually happened, not as they were supposed to happen. If your instructor says you can simply state that you followed the procedure in the *Lab Manual/documents*, be sure you still document occasions when you did not follow that exactly (e.g., "*At Step 4 we performed four repetitions instead of three, and ignored the data from the second repetition*"). If you have done it right, another researcher should be able to duplicate your experiment.

Results

This section is usually dominated by calculations, tables and figures. However, you still need to state all significant results explicitly in verbal form.

Graphics need to be clear, easily read, and well labelled (e.g. ***Figure 1:*** *Signal and Its Spectrum Component*). An important strategy for making your results effective is to draw the reader's attention to them with a sentence or two, so the reader has a focus when reading the graph.

Discussion

This section is one of the most important parts of your report, because here, you show that you understand the experiment beyond the simple level of completing it. Explain, analyse, interpret. Some people like to think of this as the "subjective" part of the report. By that, they mean this is what is not readily observable. This part of the lab focuses on a question of understanding "What is the significance or meaning of the results?"

More particularly, focus your discussion with strategies like one or more items below:

- **Compare expected results with those obtained**. If there were differences, how can you account for them? Saying "human error" implies incompetence. Be specific; for example, the instruments could not measure precisely, or calculated values did not take account of friction.

- **Analyze experimental error**. Was it avoidable? Was it a result of equipment? If an experiment was within the tolerances, you can still account for the difference from the ideal. If the flaws result from the experimental design, explain how the design might be improved.
- **Explain your results in terms of theoretical issues**. Often undergraduate labs are intended to illustrate important physical laws. Usually you will have discussed these in the introduction. In this section, move from the results to the theory. How well has the theory been illustrated?
- **Relate results to your experimental objective(s)**. To discuss if the lab objective been satisfied.
- **Analyze the strengths and limitations of your experimental design**. This is particularly useful if you designed the object you are testing (e.g., a circuit, a software, a system, etc.).

Conclusions

Conclusions can be very short in most undergraduate laboratories. Simply state what you know now for sure, as a result of the lab. The conclusion might also be a place to discuss weaknesses of experimental design, what future work needs to be done to extend your conclusions or what the implications of your conclusion are.

References

References include your *Lab Manual/documents* and any outside reading you have done. All references must conform the *IEEE Citation Reference* format[2].

Use of Visual Aids

A picture is worth a thousand words, that is, if it is done properly. The proper use of visual aids can really help the reader to understand the report. However, overuse of visual aids will detract from any points that you are trying to make. The proper choice of visual aid is also important, as an improper choice will cause the reader to skip over any visual aids, thereby diminishing the effectiveness of your report. Choose your visual aids very strategically to maximize the effectiveness of your report.

For this course, you are limited in the possibilities for visual aids since you have to use all of the tabulated data and graphs as directed in the lab manual. The only real choice in visual aids is how you present them and any extras which you can include such as image files form the oscilloscope of the different waveforms.

Schematic Drawings

It is important to use proper standard notation in the drawing of the schematics. You can use photocopies of circuit diagrams from the lab manual as long as they are correct, or are manually corrected by you. Each schematic drawing has to have a figure number and a

[2] http://www.ieee.org/documents/ieeecitationref.pdf

proper name. Each schematic has to have all of the components properly labelled with a symbolic name (i.e., a resistor named R2) and a value with units. IC's and other similar components must have the pins numbered as well. The input voltage and sink (ground) sources must be labelled with a name, value, and the type of voltage (i.e. DC or AC). If different power supplies or sinks are being used in the circuit, each must clearly identified to what parts of the circuit it is connected to.

The input and outputs of the circuit must be clearly identified in the circuit, as well as their purpose. For example the output of a full rectifier should indicate that the output is a full rectified waveform.

Charts and Other Tabulated Results

Tabulated data must have an appropriate descriptive title plus a figure number. The data must be identified as what its source is (i.e. input. output, or something in-between), representative symbols (such as V for volts), and must include the units. Tabulated data for measurements must also include theoretical results in the table as well for comparison purposes. It is also usually a good idea to include percent error, or deviation in the table as well.

Graphs and Images

Graphs must have an appropriate descriptive name and figure number. The axis must be titled, with symbol names, scale, and units. If there are multiple graphed lines on the same graph, they must be clearly distinguished from each other, and they must also be properly named to indicate what the set of data points represent (i.e., measured and calculated). It is usually a good idea to include a grid as well for the graphs to allow easy pinpointing of interesting features. When drawing graphs with a small number of data points (i.e. non-computer generated simulations), clearly identify the data points. You can clearly identify the data points by using a different colour, by circling the data point or by making the data point bold.

The following provides a comparative demonstration of proper use of graphs and/or figures within a report.

Bad Example: Figure (1) presents the output SNR S_0/N_0 as a function of γ for various values of β.

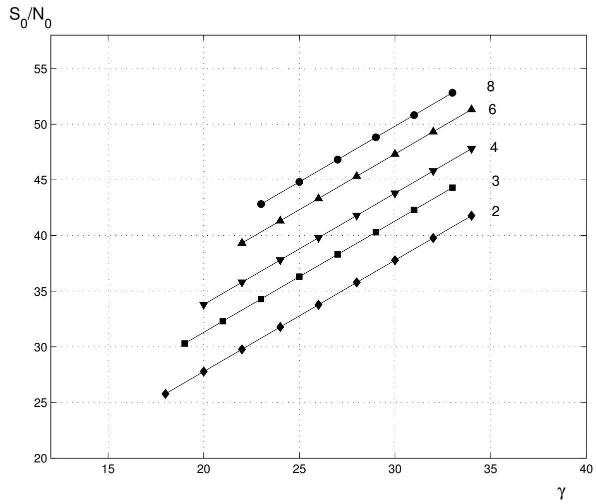

Figure 1: Performance of FM systems.

Good Example: Figure (2) presents the output SNR S_0/N_0 as a function of γ for various values of β.

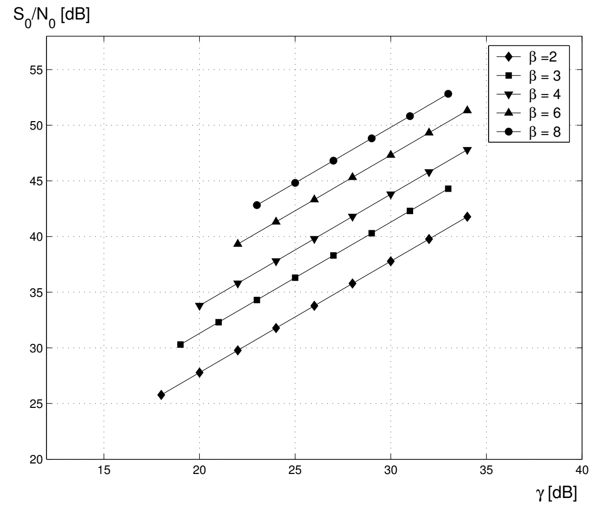

Figure 2: Performance of FM systems.

Symbols / Formulas / Equations

Symbols and formulas/equations can be extremely valuable in expressing complex concepts. It is recommended, however, that authors should use symbols and formulas/equations sparingly only when their inclusion in a report would enhance its readability. Defining symbols if they will be only used once may not be an appropriate choice. The symbols used in a formula/equation must all be previously defined or defined immediately after the formula/equation. It is also proper, to number equations and to use symbols that conform to generally accepted standards such as the use of the symbol V to represent voltage. Once symbols are defined, using them in the main body of the text will enhance the report's readability. Symbols must remain consistent throughout the report.

The following provides a comparative demonstration of proper use of symbols and formulas within a report.

Bad Example: AM signals are notoriously power inefficient. For example, the power efficiency of a standard AM signal is given by the expression:

$$\eta = \frac{{A_m}^2}{{A_m}^2 + 2{A_c}^2}, \tag{1}$$

or equivalently,

$$\eta = \frac{\mu^2}{\mu^2 + 2}. \tag{2}$$

Equations (1) and (2) indicate that the power efficiency for standard AM signals can attain a maximum value of 1/3.

Good Example: AM signals are notoriously power inefficient. Let us consider a standard AM signal generated by a single-tone signal $A_m \cos \omega_m t$ modulating the carrier $A_c \cos \omega_c t$. Let η be the power efficiency which we define as the ratio of sideband power to the total AM signal power such that:

$$\eta = \frac{{A_m}^2}{{A_m}^2 + 2{A_c}^2}, \tag{3}$$

or equivalently,

$$\eta = \frac{\mu^2}{\mu^2 + 2} \tag{4}$$

where $\mu = A_m/A_c$ is the modulation index in this single-tone modulation example. Since $\mu \leq 1$ to prevent overmodulation, we have $\eta_{max} = 1/3$ corresponding to $\mu = 1$.