A Basic Guide to Writing a Successful Laboratory Report

Written:
Jason Wells, 20 January 2004

Updated:
Marco Amrhein, 20 January 2005
Matt Magill, 12 January 2012

1 Introduction

Being a successful engineer requires more than simply being able to successfully run an experiment or execute a computation. The ability to convey information in a clear and concise manner is equally important. This document provides a guideline to writing meaningful reports that communicate data obtained in an experimental setting. Specifically, it presents several ideas for maintaining coherence, formatting suggestions, and good laboratory practices. Ultimately, the guidelines presented in this document should help students write laboratory reports for ECE 431.

2 Discussion

2.1 Coherence of a Report

The discussion in a laboratory report should flow smoothly so the reader does not have to stop and question what the intent of the author is, or purpose of a particular set of data. There are several ways to ensure that the report will concisely lead the reader through a discussion. First, the report should have a structure that makes pertinent information easy to find. Every report should begin with an abstract and/or introduction. This section clearly and concisely describes the primary objectives that were explored throughout the experiment. The introduction/abstract allows a reader to quickly determine whether the report is pertinent to whatever problem they are researching. Additionally, it should set the reader up for the general flow of discussion that will occur in the report. Next, the body of the report should follow directly from the introduction. This section should be broken into logical sub-sections where relevant data is grouped together. The body of the report presents all of the data that is obtained from experimental results as well as relevant theory that explains these results. Section headings will likely change based on the material that is covered in the experimental work. Section headings appropriate for Experiment 1 [1] might be chosen as the section headings from the experiment (see example report). Finally, a conclusion section, which summarizes the findings presented in the discussion, should be included. The conclusion could also be used to discuss difficulties encountered in the experiment or suggest possible improvements.

Correct grammar and spelling is essential within a laboratory report. Incomplete sentences and/or misspelled words tend to distract the reader from understanding the intended concepts. Additionally, most professional reports are written in a third person point of view. A consistent voice makes a discussion much easier to follow. Tables and figures should not appear before, nor significantly after, their first mention in the text. This allows the reader to quickly jump between the discussion and the relevant table or figure.

2.2 Formatting Suggestions

2.2.1 Data

Any data discussed or used in calculations should be included clearly within the report. Data needs to be presented in a concise fashion and placed close to the corresponding discussion and/or calculation. A table is a convenient method for displaying large amounts of data, and can be easily referred to throughout the discussion. To remove any ambiguity, all data and calculations need to include relevant units. It is not sufficient to assert, "The voltage was 100," since the reader must then discern whether it is 100 V, mV, or kV. Occasionally there exist experimental data that go unused within the report. Supplemental data such as this should be included in an appendix in order to avoid a cluttered discussion within the body of the report.

2.2.2 Equations and Calculations

Evaluation of experimental work often requires the use of equations and subsequent calculations. Any equation or calculation should be a part of the discussion in the report. It should be *extremely* obvious to the reader how a particular result was obtained and the reader should be able to quickly reproduce these results with the data presented. A sample equation should be provided with discussion or example calculations clearly establishing what data was used to produce a particular result. It may be appropriate to tabulate the results of repetitive calculations in the same table as the data that is used in the calculation.

An equation should be set on its own line with each variable clearly identified within the discussion. The equation should also flow seamlessly within the discussion; similar to the way you would verbally describe it to someone. As an example, consider Ohm's law, which is given by

$$V = IR\,, \tag{1}$$

where V is the applied voltage, I is the resulting current flow, and R is the resistance of the load. This removes any ambiguity regarding how a calculation was performed. For labs in ECE 431, descriptions of obvious and commonly used variables (such as line-line voltage or line-neutral voltage) can be omitted provided that the variables used are clear (i.e. V_{ll} or V_{ln}). Notice Ohm's law shown in (1) is also numbered on the right, allowing concise referencing of the equation in the discussion. To make equations neat and organized, use an equation editor such as MS Equation 3.0 that is built into MS Word. To obtain the centering of the equation on the page and the right numbering, use the Tabs option under the Format menu to set a center tab in the center of the page and a right tab at the right margin. If you plan to do a significant amount of scientific writing you may want to consider a program like Mathtype, which provides several advanced formatting and referencing functions. For students and staff within the college of engineering, a free license & download are available at the University of Illinois Webstore (http://webstore.illinois.edu/home/). Alternatively, LaTeX (http://www.latex-project.org/) provides users with the ability to fully control the typesetting of documents, and allows for seamless integration of clean mathematical notation.

Calculations are often presented in the discussion to compare experimental results to theory. Whenever such comparisons are made, a quantitative measure of the comparison should be presented. It is not sufficient to simply state qualitatively that the results are "very close" or "extremely poor". As an example, consider the relationship between line-line and line-neutral quantities in a wye connection examined in the first lab as given by

$$V_{\phi} = V_{ln} = V_{ll} \big/ \sqrt{3}\ . \qquad (2).$$

When asked to verify the relationship in (2), a percent error calculation,

$$\%error = \frac{V_{\phi,theo} - V_{\phi,meas}}{V_{\phi,theo}} \times 100 = 0.122\%\ , \qquad (3)$$

serves as an appropriate quantitative measure. Whenever possible, such comparisons should be applied in order to provide the reader with a clear picture of how well the results agree with the established theory.

2.2.3 Tables and Figures

Tables and figures are often included in the report to convey data trends or depict a concept graphically. These should appear as soon as possible following the first mention of them in the discussion. It is generally appropriate to include them in logical breaks in the text such as at the end of a paragraph or section. Also, it might be appropriate to keep them at the top or bottom of a page so that the text is blocked together and easy to follow. A figure or table should never appear in a report if it is not explicitly referenced in the discussion. Every figure and table need be clearly labeled with a caption including a number and description. For example, Table 1 below presents a typical set of data that might be obtained in the Part A of Experiment 1 [1]. When referring to a figure (table) in the discussion, it should be cross-referenced by number with Figure (Table) being capitalized, as was done in the previous sentence. It is acceptable to abbreviate as Fig., provided it is not the first word in a sentence. Tables and figures should be clearly legible with all quantities appropriately labeled with units. Throughout the class, several oscilloscope plots will be taken and can be inserted into the report as figures. Figure 1 shows a representative oscilloscope screen-capture displaying the currents in a motor drive system. Note that the units and axes should be clearly displayed on all figures. Figure 2 provides a collection of data points. When appropriate, a legend indicating the meaning of each data set should be included.

Table 1. Experimental Data and Results from the Wye-Connected Resistive Load.

	Line Current (A)	Phase Current (A)	Line-Line Voltage (V)	Phase Voltage (V)	Phase Shift (deg)	One-Wattmeter P_{obs} (W)	Total 3-Phase Reactive Power (Vars)	Two-Wattmeter (P_1) (W)	Two-Wattmeter (P_2) (W)	Total 3-Phase Power (W)
Phase A (A-B)	1.38	1.38	240.6	138.4	0	0	0	289	290	579
Phase B (B-C)	1.38	1.38	241.4	138.9	0	-	-	-	-	-
Phase C (C-A)	1.36	1.36	240.2	139.2	0	-	-	-	-	-
Averages	1.37	1.37	240.7	138.8	0	-	-	-	-	-

2.2.4 References

Appropriate referencing allows a report to be both more useful and easier to follow for the reader. In the context of ECE 431, referencing the lab manual is often appropriate when discussing the procedure and circuit diagrams that were used in an experiment. Occasionally it will also be fitting to cite theory from a text such as the ECE 431 textbook [2]. This saves the effort of regurgitating material that can be easily found elsewhere. Outside of this class, referencing typically provides a historical and theoretical context of the work, and allows the reader to research the concepts upon which the experiment is based.

There are numerous styles that are used for referencing sources and the report should be based upon whatever style is appropriate for the intended audience. For this class, the IEEE style format is recommended. Complete information for IEEE authors can be found in [3] including standard abbreviations. In this class it may also be beneficial to follow the reference guide put together by the ECE publication office [4]. Again, students who will be extensively writing technical reports should consider software such as Endnote which offer several advanced capabilities for managing and citing references. A limited demo is available from www.endnote.com; however, is not recommended for ECE 431 purposes. Additionally, BibTeX (http://www.bibtex.org/) provides users with an intuitive way to compile and correctly cite references within technical documents.

2.3 Laboratory Practices

A successful laboratory report begins with successful laboratory practices. Writing reports becomes infinitely less difficult when meaningful data is available. This begins by understanding the equipment that is used in the experiment. Be certain that laboratory equipment is set to the appropriate range for the measurement being taken. Also, be aware of what the expected results are for whatever experiment is being performed. This helps catch mistakes as they are being made rather than when trying to write the report.

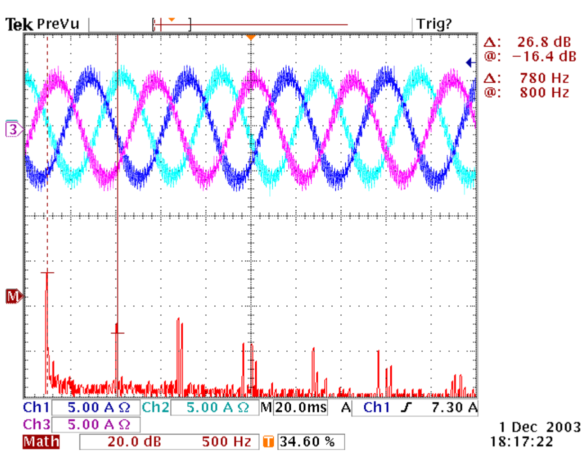

Figure 1. Three-phase currents in a 500 W rated motor drive system with harmonic elimination up to the 31st harmonic.

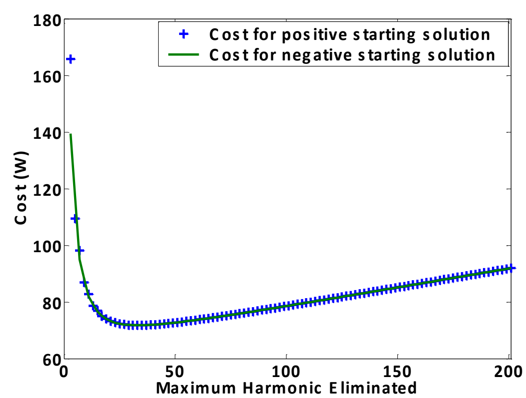

Figure 2. Cost function evaluation for various harmonic elimination solutions.

As an engineer, it is important to maintain adequate records of experimental work. Typically, this will be a formal laboratory notebook that can be used as a legal document if properly maintained. In this class, a permanently bound notebook with pre-printed page numbers is required, and all recordings must be made with pen. The purpose of the notebook is to maintain sufficient documentation such that a given set of results can be reproduced. Typical information includes:

1. Serial numbers for any specialized equipment used (In ECE 431 it is sufficient to record the bench serial number and the machine nameplate data).
2. Any circuit diagrams that differ from the manual.
3. Any important procedural changes that deviate from the manual.
4. Experimental data.
5. Dated signatures of those involved in the research (and typically a witness signature if being maintained as a legal document).

Copies of laboratory recordings must be included in the reports for this class, and are often kept available for reference in a professional setting.

3 Conclusions

This document has presented several suggestions for writing a successful laboratory report. It is not intended to supplant more complete writing texts that cover subtleties well beyond the scope of this discussion. Rather, it is intended to make students aware of some of the more basic concepts in technical writing and expose students to a few helpful tools that exist. Appendix A includes a reference of the key points that were presented. If you have any additional questions or suggestions for improving this guide, feel free to discuss it with any of the T.A.s or with your professor.

References

[1] P.W. Sauer, P.T. Krein, P.L. Chapman, *ECE 431 Electric Machinery Course Guide and Laboratory Information,* University of Illinois at Urbana-Champaign, 2005.

[2] A.E. Fitzgerald, C. Kingsley, Jr., and S.D. Umans, *Electric Machinery 6th Edition.* New York: McGraw-Hill 2003.

[3] IEEE Periodicals, "IEEE Citation Reference," Sep. 2009, http://www.ieee.org/documents/ieeecitationref.pdf

[4] ECE Publications Office, "Reference Guide: IEEE Style," July 2010, https://wiki.engr.illinois.edu/download/attachments/31394450/IEEE-refguide.pdf.

Appendix A: Quick Reference of Important Suggestions

1. Coherence of a Report
    a. Break the report into appropriate sections including an introduction, body, and conclusions.
    b. Discussion should have smooth transitions and be easy to read.
    c. Correct grammar and spelling is essential.
    d. Write in a 3^{rd} person point of view.
    e. Tables and figures should appear immediately following their first introduction in the discussion.

2. Data
    a. Present large amounts of data in a concise way such as a table when necessary.
    b. Correct units are required on all data.
    c. Only place data in the report if it is actually used.

3. Equations and Calculations
    a. Equations should be on their own line and be numbered.
    b. Every variable used in an equation should be clearly defined. For this class, obvious quantities such as line-line voltage or line current need not be explicitly defined provided that the variable is appropriately descriptive (i.e. V_{ll}).
    c. When discussing equations, refer to them by number.
    d. Equations must be properly formatted using an equation editor such as MS Equation or Mathtype.
    e. Results of repetitive calculations can be summarized in a table.
    f. Whenever appropriate, use quantitative measures such as percent error calculations to evaluate experimental results.

4. Tables and Figures
    a. Similar to data, tables and figures should appear immediately following their first mention in the discussion.
    b. Every table or figure requires a number and descriptive caption.
    c. Every table or figure should be clearly legible and include a legend and axis units when appropriate.

5. References
    a. Do not regurgitate the laboratory procedures. If necessary, cite them in the discussion using an appropriate reference. Deviations from procedure should be discussed in the report.
    b. IEEE referencing style should be used for this class
    c. IEEE style indicates that references are numbered in the order that they appear in the discussion.
    d. IEEE style indicates that references cited in the discussion can be referred to directly by number.

6. Laboratory Practices
    a. Take sufficient data in the lab to be able to recreate results.
    b. Have a general understanding of what is expected for results in a particular experiment.
    c. Data sheets must be submitted with the report as an appendix.