How To Write A Good Lab Report (Using LaTeX)

Waleed Al-Nuaimy
Department of Electrical Engineering and Electronics

September 20, 2013

Abstract

This document describes what is expected from an engineering laboratory report. While this is not a definitive guide to report-writing, it is intended as a guide to assist in documenting and presenting your experimental work. Appended to this guide are some real examples of common mistakes that should be avoided. It is expected that lab reports are prepared using the LaTeX typesetting system, adopting pne of the standard report templates provided on VITAL.

Contents

1 Introduction

The purpose of a laboratory report is to document your experimental findings and to communicate their relevance and significance. For this to be effective, it must demonstrate your comprehension of the underlying concepts and principles the experiment was intending to examine. It is not sufficient to simply record the experimental results. To facilitate this communication, scientists and engineers have adopted a common format for their technical writing, consisting of a number of components, as detailed below. This communication skill is also essential for the authoring of project dissertations, theses and scientific articles and papers (further guidance can be sought from such references as [1], [2], [3], [4] or [5]).

1.1 LaTeX

When preparing formal reports, you are **strongly** required to use LaTeX; this is a typesetting "language" intended for technical reporting, and allows you to produce professional and well-structured documents. LaTeX is built around the philosophy that authors need only concentrate on the logical structure of their document, rather than worrying about formatting. By using LaTeX, you are much less likely to loose marks for poor report formatting, and your technical writing will be of a high presentational standad. There are several free LaTeX distributions and editors; on campus you can install MikTex, but to get started I suggest you sign up to use the free online LaTeX editor and compiler at www.sharelatex.com.

There are plenty of online tutorials (such as [6], [7] and [8]) to assist you in mastering LaTeX, as well as some free LaTeX editors to help in the editing of the text files. You are encouraged to self-learn this aspect. It is hoped that mastering LaTeX will allow you to produce high-quality lab and project reports throughout your studies at Liverpool and beyond.

1.2 Report Structure

The general agreed structure of a scientific report is as follows:

1. Title page, to contain
    - Name and date
    - Abstract / Synopsis
    - Plagiarism and collusion declaration
    - Table of contents
2. Introduction
3. Materials and Methods/Procedure
4. Results and Analysis
5. Discussions and Conclusions
6. References (if any cited)
7. (optional) Appendix

1.3 Title Page

This should contain the name and number of the experiment, the module to which it contributes, and the student ID of the author (please note names must **not** be used on reports, as marking

is anonymous), his/her/their group number, and the date the experiment was carried out. The title page should also contain an abstract; this summarises the report: its purpose, key findings and conclusions, with or without mention of the procedure, in roughly 50 to 100 words. The abstract is generally followed by a Table of Contents. This LaTeXtemplate puts all these components together onto a single page using the `titlepage` environment.

Immediately after the Abstract, there is a box for you to write out a statement concerning plagiarism and collusion, similar to that at `http://pcwww.liv.ac.uk/~wax/downloads/declaration.png`.

1.4 Introduction

Include a statement of the problem to be investigated, and why is addressing this problem worthwhile or important. This section should also introduce the history and theoretical background of the problem, a brief statement of the general procedure adopted and hint at expected results. This section is sometimes broken down into subsections: Objectives and Theoretical Background.

1.5 Materials and Methods

The materials list can be a simple list of all the equipment/apparatus used, in as much detail as possible (eg. mention the make/model of things like signal generators, the values of all components, the exact model of any development boards used etc). If you are using software, the name and version of the software is important.

The Method/Procedure section describes the experimental process in chronological order (i.e. in the order in which they happened). If you did not follow the documented procedure for any reason, make sure this is mentioned (e.g. "At step 4 four repetitions were performed instead of three, and the data from the second repetition was ignored. This is due to a circuit fault that was discovered that called the accuracy of these readings into question.")

If you include any figures, make sure you caption them, with a clear label and number (eg. "Figure 1. Circuit diagram of resonance circuit used in Part 1 (taken from [9])"). It is important that you **refer to** your figures, otherwise they will be ignored, and you will receive no credit for including them. The same applies to tables. Be sure to mention the source of your figure, if you have copied it from somewhere. Captions for figures appear beneath the figure; table captions appear above the table. Using LaTeX, each figure would have a `label`, such as `\label{OpAmp}` allowing you to then cite the figure easily by saying "`as shown in Fig.~\ref{Fig:OpAmp}...`"[1], and LaTeXwill automatically insert the correct figure number! Graphs should have both axes clearly annotated, mentioning any units (eg. Volts, Hz).

1.6 Results

This is where you describe the important qualitative and quantitative observations from the experiment. Data should be tabulated and/or graphed. Graphs must always be captioned (as with figures, above), and axes clearly annotated with units. Always follow your graphs with a brief description, demonstrating your understanding of what has been plotted (eg. "The

[1]The tilde (∼) character in LaTeX is a non-breaking space, i.e. a space that will not break at the end of a line, so the "Fig." will never be separated from the number that follows it. This is equivalent to a Ctrl-Shift-Space in Microsoft Word

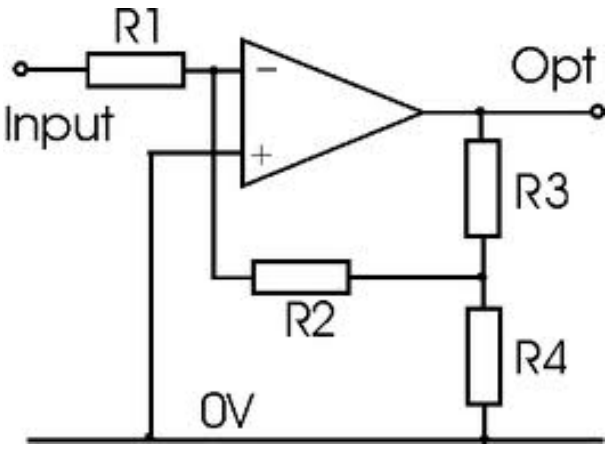


Figure 1: Circuit diagram of non-inverting amplifier circuit used in Part 1 (taken from [9])

graph in Fig. 4 illustrates the frequency response of this circuit, with a clear resonance peak at 15 kHz.") as tables and graphs are rarely self-explanatory. If the results differ from what was expected, explain both **how** (i.e. in what way) and **why** (i.e. possible reasons behind this behaviour) when referring to these results.

If you have experimental notes from your log book taken during the experiment, these should be placed in the Appendix, but referred to here (eg. "Refer to logbook results in the Appendix, page 8.") This is often the section where you answer any questions that are part of the lab experiment. Both the question and the answer must be written. This section may also contain an **Analysis** subsection where the results are subjected to some mathematical or computational analysis, presenting further results to be described here, and discussed more fully in the following section.

1.7 Discussion

The Discussion section allows you to fully discuss and interpret the results and the results of the any analysis carried out. It is also important here to relate your findings to the experimental objectives, i.e. do your results support the theoretical background, and have the objectives of the experiment been met? Are the results reliable and/or significant?

This will involve comparing your obtained results with those expected from the theory. Accounting for any discrepancies is an important aspect of your experimental report, and should also go here. If the difference was a result of experimental error, comment on the nature and source of these errors (human error, systematic error, random error, etc) and try to quantify this error as it propagates from measurements to calculated values. If the errors resulted from the design of the experiment itself, comment on how the design might be improved. If you feel the lab script itself could be improved, here is the place to make you suggestions.

In this section, you may also wish to detail any additional work or reading you have done related to this experiment. You may have carried out some simulation or modelling, or may have read a scientific article about the topic, and may wish to discuss this here. If there were any particular circumstances that hindered your progress during this experiment, or if you were unable to complete part of the experiment for whatever reason, you can elaborate on this here.

1.8 Conclusions

This final section contains a brief statement to summarise the outcome of the experiment, and a statement outlining to what extent the objectives of the experiment have been met, and what has been learnt as a result of this. In some ways the Conclusions section is a reflection of the Abstract, reiterating what the experiment was aiming to achieve, and summarising the outcomes. It can also be thought of as a summary of the Discussion section.

2 Referencing

If you ever find yourself referring to a previously reported method, book, website, article or even your lab script or lecture notes, you must insert a citation (like this [10]. Every quotation must be referenced. Failure to do this will result in a charge of plagiarism, and is a violation of scientific and literary ethics. There are a number of acceptable formats for listing references, please read up on these separately. You are encouraged to adopt the IEEE referencing style [11], [12], provided automatically by the LaTeXinstruction `\bibliographystyle{IEEEtran}`. Please look at the file `MyRefs.bib` and references [8] and [1] for guidance on how to correctly format the BibTeX bibliography file for LaTeXto process correctly.

3 Style and Formatting

Using LaTeXwill make formatting less of a worry, as it will ensure your report conforms to the adopted format and style, but the guidelines below can be used for guidance in situations where LaTeXmay not be available. There are no hard and fast rules, but reports should generally be written in a standard font (such as Times or Arial) of size 11 point, and be used consistently throughout the report. Margins should be wide enough to allow comments to be written when marked, and the left margin should allow enough space for binding (if appropriate). It is expected that all equations, figures and tables are numbered. When citing references, referring to equations or figures, or mentioning values with units, use a non-breaking space (Ctrl-Shift-Space or `~` in LaTeX) to ensure the two parts are kept together (e.g. `a frequency of 10~kHz`, `as in Figure~\ref{Fig:OpAmp}`).

Keep the use of colour to a minimum, and avoid decorating the pages with unnecessary features such as borders. Try to always write in the third person, and in the passive voice without use of the first person ("I" or "we"), e.g. "The circuit in Figure 1.5 was connected, and voltage measurements were taken as the frequency was varied." Needless to say, it is expected that all pages are numbered, and that the report be free from spelling and grammatical errors, and that capital letters should be used appropriately. All values should appear with the correct units, etc.

To avoid inadvertently over-writing your work, it is good practice to maintain a level of version control by adopting a sensible and consistent file naming convention that includes your surname, the title of the report, and the version number, such as `alnuaimy-report-guide-ver02.pdf`, or `Smith-Exp-17-ver03.pdf`; avoid ambiguous filenames such as `report.pdf`.

References

[1] WikiBooks, "LaTeX bibliography management," http://en.wikibooks.org/wiki/LaTeX/Bibliography_Management, 2011.

[2] D. Mowshowitz, "How to write a laboratory report," http://www.columbia.edu/cu/biology/faculty/mowshowitz/howto_guide/lab_report.htm, Columbia University, Sep. 2006.

[3] P. Bibby, "How to write a laboratory report," http://www.psychology.nottingham.ac.uk/staff/dmr/c81mpr/HOWTOWRITEALABORATORYREPORT.pdf, University of Nottingham, Sep. 2006.

[4] C. R. Brune, "How to write a lab report," http://inpp.ohiou.edu/~brune/phys371/how_to_write_a_lab_report.pdf, Physics and Astronomy Department, Ohio University.

[5] SIR-Rays, "How to write a lab report," http://www.sir-ray.com/HowToWriteALabReport.htm, The Space, Planetary and Astronomical Cyber-Experience.

[6] "LaTeX for newbies," http://latex.mschroeder.net/index_en.php.

[7] J. Clark, "LaTeX tutorial," http://ece.uprm.edu/~caceros/latex/introduction.pdf, Department of Electrical and Computer Engineering, University of Puerto Rico Mayagez, 2002.

[8] A. J. Hildebrand, "Bibliographies - stylistic conventions for bibliographies in mathematical writing," http://www.math.uiuc.edu/~hildebr/tex/bibliographies.html, Department of Mathematics, University of Illinois at Urbana-Champaign, 2007.

[9] Radio-Electronics.com, "Inverting operational amplifier circuit," http://www.radio-electronics.com/info/circuits/opamp_inverting/op_amp_inverting.php, University of Idaho, 2006.

[10] Library and Learning Resources, "How to write references," http://library.bcu.ac.uk/references.pdf, Birmingham City University, 2011.

[11] D. Graffox, "IEEE citation reference," http://www.ieee.org/documents/ieeecitationref.pdf, Birmingham City University, Sep. 2009.

[12] P. Druker, "Advanced technical writing," http://www.class.uidaho.edu/adv_tech_wrt/resources/sources/bibliographic_ieee_format.htm, University of Idaho, 2006.

[13] WikiBooks, "LaTeX advanced mathematics," http://en.wikibooks.org/wiki/LaTeX/Advanced_Mathematics, 2011.

Appendices

A Common Elements in LaTeX

Your appendices may typically include such elements as raw data, data sheets, source code (program listings), photographs, calculations, graphs, pictures or tables that have not been included in the report itself. Sometimes this may involve embedding these as images within the main document. Make sure you refer to each appendix at least once in your report, otherwise they will be ignored.

A.1 Tables

This section contains some table templates to help you create your own tables using LaTeX. Look at this `.tex` file to see how the table elements are constructed, and use it as a template for your own tables.

The summary of the experimental results is presented in Table 1

Table 1: Note that table captions are placed above the tables, not below as for figures

P (W)	V (V)	I (A)
0.0 ± 0.01	0.0 ± 0.01	0.0 ± 0.01
0.1	0.2	0.3
0.1	0.2	0.3
0.1	0.2	0.3
0.1	0.2	0.3
0.1	0.2	0.3
0.1	0.2	0.3
0.1	0.2	0.3

Table 2: Resistance and Temperature of the Filament

R (Ω)	T (K)	$1/T$ (K^{-1})	$\ln P$
151.00±3.92	828.35±23.46	1.2072×10^{-3}	-13.29
157.12±3.71	856.88±22.25	1.1671×10^{-3}	-12.64
162.53±3.49	881.99±21.02	1.1338×10^{-3}	-12.33
166.67±3.33	901.14±20.13	1.1097×10^{-3}	-11.90
171.84±3.17	924.98±19.25	1.0811×10^{-3}	-11.25
176.84±3.04	947.96±18.53	1.0549×10^{-3}	-10.77
181.46±2.90	969.13±15.49	1.0319×10^{-3}	-10.20
157.12±3.71	856.88±22.25	1.1671×10^{-3}	-12.64
162.53±3.49	881.99±21.02	1.1338×10^{-3}	-12.33
166.67±3.33	901.14±20.13	1.1097×10^{-3}	-11.90

A.2 Maths

Mathematical expressions can be included in LaTeXdocuments easily by surrounding them in `$` signs, such as f, δx, Ω_2, $y = mx + b$ or $\mu = \frac{1}{N}\sum_{i=1}^{N} x_i$. Numbered equations can be created just as easily using the `equation` environment:

$$\mu = \frac{1}{N}\sum_{i=1}^{N} x_i. \tag{1}$$

When making reference to the above equation, you simply need to mention the label, as in "`...as shown in Equation~\ref{eq:mean}.`", and the Equation number will be inserted automatically. If you need to show several lines of mathematical expressions, you can use the `eqnarray` environment as below:

$$\begin{aligned} P &= IV && (2)\\ &= I^2R && (3)\\ &= \frac{V^2}{R} && (4) \end{aligned}$$

Further guidance on writing and manipulating mathematical expressions, symbols and equations can be found online in references such as [13].

A.3 Program Listings

Program listings and source code can be neatly incorporated into your reports by including them in a `\lstlisting` environment, as in Listing 1 below, or if you are constantly editing your program, you could import the code directly from the source itself (provided you've uploaded it to your ScribTeX workspace). In this way, whenever you modify the source, all you need to do is recompile the LaTeXcode and your report document will automatically be updated. The command to use would be something like `\lstinputlisting{MY_CIRCLE.m}`.

Listing 1: This is how to include some source code

```
[x,y] = MY_CIRLCLE(x_centre, y_centre, radius)

% MY_CIRCLE.m - A MATLAB function to draw a circle on the screen
% Syntax is:
%             [x,y] = MY_CIRLCLE(x_centre, y_centre, radius)
%
% Waleed Al-Nuaimy, 1st July 2011

theta = linspace(0, 2*pi, 200);          % in radians
x     = x_centre + radius*cos(theta);    % radius can be negative!
y     = y_centre + radius*sin(theta);
plot(x,y,'r-')                           % connect using red line
axis('equal')                            % to preserve aspect ratio
ylabel('y')
xlabel('x')
title(['Circle centred at (',num2str(x_centre),',', ...
       num2str(y_centre),') of radius ',num2str(radius)])
```

B Examples of how NOT to write a report

These are some common mistakes try to avoid them!

Abstract

This project is called image stabilization, obviously, it is about how to deal with a series of images and use some special technologies to reach the goal of stabilization. This project is based on some mathematical method and modulation of Matlab. Since the project is complicated and each step needs a code to realize a subtask, it should be worked slowly and carefully to get the final result. Besides, this project is of high freedom, so the quality of the result depends directly on what our group learned during the period.

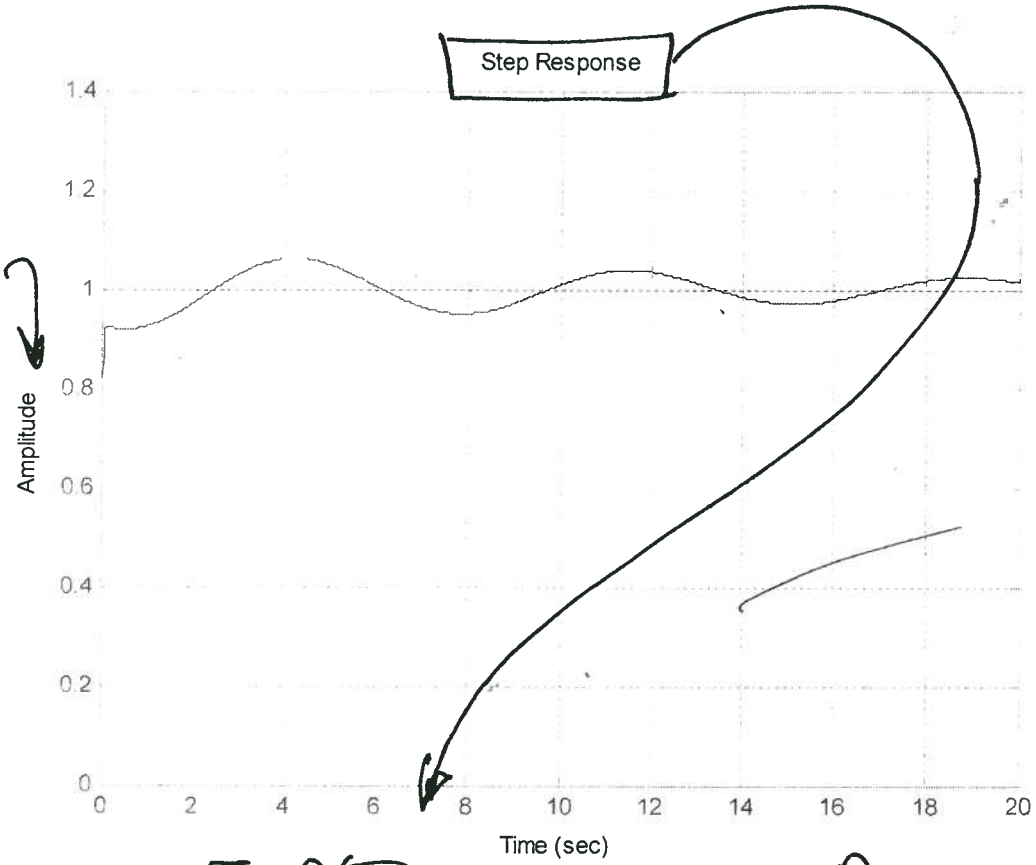
Contents

? Longer time period shows overshoot ?

```
function [ num, den ]=t5cc
Kp=1;
Ki=8;
Kd=10;
num=[5*Kd 5*Kp 5*Ki];
den=[1 4+5*Kd 3+5*Kp 5*Ki];
t=0:0.01:20;
step(num,den,t)
grid on
end
```

add comments

Add a caption.



unit?

Figure 5. Step response of .....

A derivative control can stabalise the system by reducing the overshoot, and improving the transient response. This is done by the derivative term Kd, slowing the rate of change of the controller, thus reducing the magnitude of the overshoot.

Discuss the plot and describe it.

poles = ?

-3

References

http://en.wikipedia.org/wiki/Bode_plot ← Don't cite Wikipedia.

It is expected that the neurons can communicate with each other, finish some special task together, so the theory of multi-agent may provide potential benefit.

The object programming technique is widely used in the program language like C++ and Java. As we get the electronic neuron cell which can be programmed to finish some complex works, it is expected that the object programming technique and Java can produce a language for neuron communication and finish designed task or make neuron program by it self. This can be supported by the DHNN.

Refer to the figure(s)

NOT CLEAR AT ALL

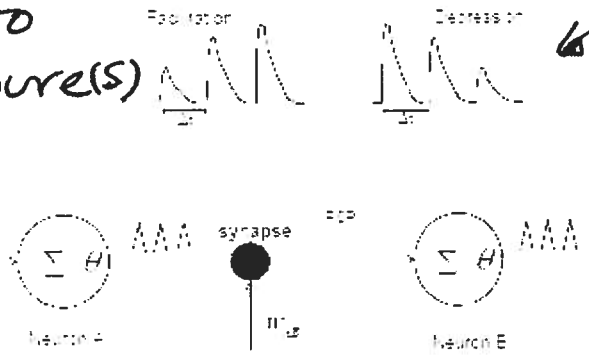


Fig. 1. Illustration of a fragment of spiking neural networks with synaptic junction. θ represents the threshold. The inset show the facilitation and depression behavior at many synapses with impulse separated by time Δt

Caption? Source?

Neuron Cell (Wikipedia 2010)

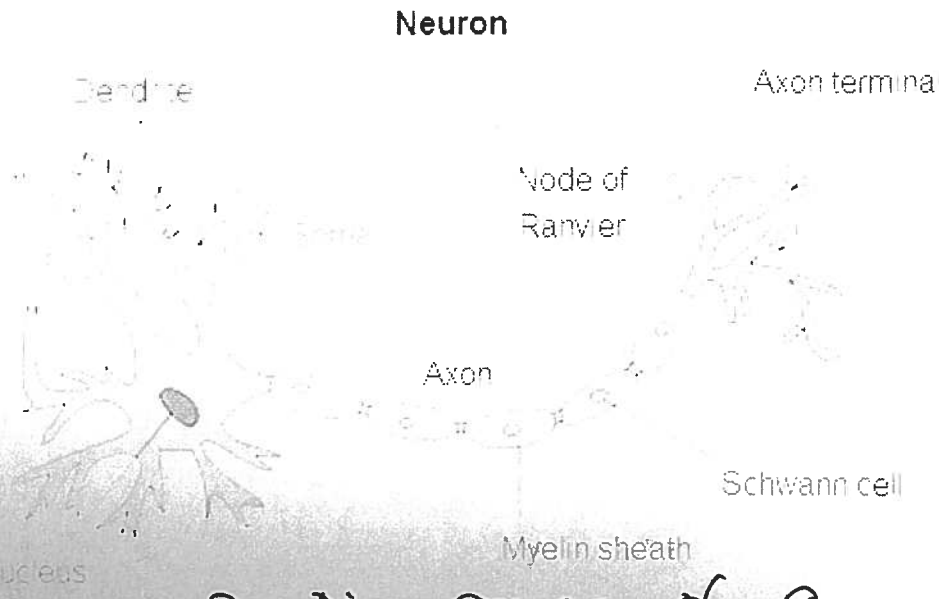


Figure 2. Diagram of a

NB: Don't cite Wikipedia!

No insight.
No imagination.
No creativity.
No self-assessment

There is no reflection or thought about the relevance or significance of this project.

Conclusion

To sum up digital control of volume and left right audio controller is an important device in human life. It has been used in many different situations not just for entertainment.

If the issues mentioned in the results chapter could be overcome, this would be in great use for the industry of audio technology and for the purpose of entertainment.

REFERENCES

1 = Electric circuits, second edition Theodore f. Bogart, jr. The university of Southern Mississippi glencoe macmillan/mcgraw-hill school publishing company. 1992.

2 = http://www.allaboutcircuits.com/vol_2/chpt_6/2.html

Author? organisation?
Title? Date?

Capitalise: publishers, authors and titles

Two references: insufficient for a project of 4-weeks duration!

7. References:

[1] http://www.berr.gov.uk/files/file29845.pdf

[2] http://www.berr.gov.uk/files/file54298.pdf

[3] http://www.rsc.org/delivery/_ArticleLinking/DisplayArticleForFree.cfm?doi=b616511g&JournalCode=CC

[4] http://en.wikipedia.org/wiki/Organic_semiconductor

[5] Jasprit Sight "*Semiconductors Devices-An Introduction-*", McGraw- Hill International edition, 1994.

[6] Dr Munira Raja, "Seminar on Organic Electronics", 2008

[7] Dr Munira Raja, "Organic Electronics" (incomplete reference)

Add Title, author, organisation, date and date accessed.

Don't cite Wikipedia

Book? Mention publisher.

M Raja

or

Raja, M.