A Microcontroller Based Fuzzy Logic Controller Development for the Analysis of Float Currents of Batteries

TESI DI LAUREA MAGISTRALE IN

ENERGY ENGINEERING-INGEGNERIA ENERGETICA

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# Abstract

The aim of this thesis is to design and develop a new controller algorithm to be implemented on a battery testing device. The testing device (called “Floater”) has already been designed and developed to measure the float current. The primary goal of the controller is to charge the battery under test to the amount that counteracts the natural self-discharge currents called float currents – caused by phenomena such as overhang, polarization, etc. – following the transient phase. The previous controller was a PID type and tuned only for a specific type of battery; therefore, in order to use the test device on a new model of battery, manual efforts were required to tune the new gains for the PID controller. To develop a new controller to tune itself without the need for manual tuning of the PID controller gains, a fuzzy logic interface was adopted.

Pg.2

Pg.3

Pg.4

**Key-words:** Li-ion Battery, Calendric Aging, Float Current, PID Controller, Fuzzy Logic

Here goes the Abstract in English of your thesis followed by a list of keywords. The Abstract is a concise summary of the content of the thesis (single page of text) and a guide to the most important contributions included in your thesis. The Abstract is the very last thing you write. It should be a self-contained text and should be clear to someone who hasn’t (yet) read the whole manuscript. The Abstract should contain the answers to the main scientific questions that have been addressed in your thesis. It needs to summarize the adopted motivations and the adopted methodological approach as well as the findings of your work and their relevance and impact. The Abstract is the part appearing in the record of your thesis inside POLITesi, the Digital Archive of PhD and Master Theses (Laurea Magistrale) of Politecnico di Milano. The Abstract will be followed by a list of four to six keywords. Keywords are a tool to help indexers and search engines to find relevant documents. To be relevant and effective, keywords must be chosen carefully. They should represent the content of your work and be specific to your field or sub-field. Keywords may be a single word or two to four words.

**Key-words:** Li-ion Battery, Calendric Aging, Float Current, PID Controller, Fuzzy Logic

# Abstract in lingua italiana

Qui va l’Abstract in lingua italiana della tesi seguito dalla lista di parole chiave.

**Parole chiave:** qui, le parole chiave, in italiano, della tesi.

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# Introduction

This document is intended to be both an example of the Polimi WORD template for Master Theses, as well as a short introduction to its use. It is not intended to be a general introduction to WORD itself, and the reader is assumed to be familiar with the basics of creating and compiling WORD documents.

For nay doubt refer to: <https://support.microsoft.com/en-us/office>

Use the English version of Word.

To see properly the format, use the “*Paragraph mark* (Paragraph Show / Hide button in Word)”.

The cover page of the thesis must contain all the relevant information: title of the thesis, name of the Study Programme and School, name of the author, student ID number, name of the supervisor, name(s) of the co-supervisor(s) (if any), academic year. Be sure to select a title that is meaningful. It should contain important keywords to be identified by indexer. Keep the title as concise as possible and comprehensible even to people who are not experts in your field. The title has to be chosen at the end of your work so that it accurately captures the main subject of the manuscript.

Since a thesis might be a substantial document, it is convenient to break it into chapters. Be sure to be confident with “*Style*” and “*Section breaks*”. Chapters titles are identified by the “*Heading 1*” and numbered by “*Multilevel list*” and “*Numbering*”.

To start a new chapter, end the previous one with “*Section breaks-odd page*”.

The header of the first page of the chapter is different from the even and from the odd page of the chapter itself. In the header, a two rows-table (with no-borders) is present: the header in the first page contains the page number (*Insert-Header-Page number*) on the right; the even page contains the page number on the left and the chapter title on the right (*Insert-Quick Parts-Field-StyleRef-Heading 1 and Paragraph Number*).

Chapter title color corresponds to the HEX: #728FA5.

# Chapter one

In this chapter additional useful information are reported.

## Section and subsection

Chapters are typically subdivided into sections and subsections, and, optionally, subsubsections, paragraphs and subparagraphs. All can have a title, but only sections and subsections are numbered. A new section is created by “*Heading 2*” the sub-sections are created by “*Heading 3*” and so on. To number or not the section: *Multilevel list*” and “*Numbering*”.

## Equations

This section gives some examples of writing mathematical equations in your thesis.

Maxwell’s equations read:

|  |  |  |
| --- | --- | --- |
|  |  | (1.1a) |
| (1.1b) |
| (1.1c) |
| (‎1.1d) |

The equations must be labeled and cited in the text, such as Equation (1.1a), Equation (1.1b), Equation (1.1c) and Equation (‎1.1d) need to be cited in the text. To automatically name the equations and to cite them use “*References, Insert Caption and Cross Reference*”.

The following Equations (‎1.2), (‎1.3), (‎1.4) and (‎1.5) show the same equation as before, with multiple global references rather than sub-references and without brace:

|  |  |  |
| --- | --- | --- |
|  |  | (‎1.2) |
|  | (‎1.3) |
|  | (‎1.4) |
|  | (‎1.5) |

Equation (‎1.6) is the same as before, but with just one label:

|  |  |  |
| --- | --- | --- |
|  |  | (‎1.6) |

## Figures, Tables and Algorithms

Figures, Tables and Algorithms have to contain a Caption that describe their content, and have to be properly reffered in the text.

### Figures

Insert a High-definition image and take care about “*Wrap*” and “*Anchor*” to avoid text sliding. You can also insert the image in a one-row table with no-borders.

Remember to cite the Figure ‎1.1 using “*References-Cross reference-Figure*” after having insert the caption “*References-Insert caption-Figure*”.



Figure ‎1.1: Polimi logo.

The color of the caption is HEX: #728FA5

Figures can also contain multiple sub-figures (better use no-border table) with their own caption and label, e.g. Figure ‎1.2a and Figure ‎1.2b.

|  |  |
| --- | --- |
| (a) One PoliMi logo. | (b) Another PoliMi logo. |

Figure ‎1.2: This is a very long caption that you don’t want to be displayed on the List of Figures.

### Tables

In the following examples of tables are reported. Remember to label and to cite them such as in Table ‎1.1. Cell color HEX #8EA5B6.

|  |  |  |  |
| --- | --- | --- | --- |
|  | **column1** | **column2** | **column3** |
| **row1** | 1 | 2 | 3 |
| **row2** | α | β | γ |
| **row3** | alpha | beta | gamma |

Table ‎1.1: Caption to be displayed in List of Tables.

You can also consider to highlight selected columns or rows in order to make tables more readable (Table ‎1.2 and Table ‎1.3).

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **column1** | **column2** | **column3** | **column4** | **column5** | **column6** |
| **row1** | 1 | 2 | 3 | 4 | 5 | 6 |
| **row2** | a | b | c | d | e | f |
| **row3** | α | β | γ | δ | φ | ω |
| **row4** | alpha | beta | gamma | delta | phi | omega |

Table ‎1.2: Highlighting the columns.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **column1** | **column2** | **column3** | **column4** | **column5** | **column6** |
| **row1** | 1 | 2 | 3 | 4 | 5 | 6 |
| **row2** | a | b | c | d | e | f |
| **row3** | α | β | γ | δ | φ | ω |
| **row4** | alpha | beta | gamma | delta | phi | omega |

Table ‎1.3: Highlighting the rows.

### Algorithms

Pseudo-algorithms can be reported as in Algorithm 1.

|  |  |
| --- | --- |
| **Algorithm 1** Name of the Algorithm | |
| 1: | Initial instructions |
| 2: | **for** *for – condition* **do** |
| 3: | Some instructions |
| 4: | **if** *if – condition* **then** |
| 5: | Some other instructions |
| 6: | **end if** |
| 7: | **end for** |
| 8: | **while** *while – condition* **do** |
| 9: | Some further instructions |
| 10: | **end while** |
| 11: | Final instructions |

## Theorems, propositions and lists

### Theorems

Theorems have to be formatted as:

**Theorem 1.1.** *Write here your theorem.*

*Proof.* If useful you can report here the proof.

### Proposition

Propositions have to be formatted as:

**Proposition 1.1**. *Write here your proposition.*

### Lists

How to insert itemized lists:

* first item;
* second item;
* third item.

How to insert numbered lists:

1. first item;
2. second item;
3. third item.

## Use of copyrighted material

Each student is responsible for obtaining copyright permissions, if necessary, to include published material in the thesis. This applies typically to third-party material published by someone else.

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You have to be sure to respect the rules on Copyright and avoid an involuntary plagiarism. It is allowed to take other persons’ ideas only if the author and his original work are clearly mentioned. As stated in the Code of Ethics and Conduct, Politecnico di Milano promotes the integrity of research, condemns manipulation and the infringement of intellectual property, and gives opportunity to all those who carry out research activities to have an adequate training on ethical conduct and integrity while doing research. To be sure to respect the copyright rules, read the guides on Copyright legislation and citation styles available at:

https://www.biblio.polimi.it/en/tools/courses-and-tutorials

You can also attend the courses which are periodically organized on "Bibliographic citations and bibliography management".

## Bibliography and citations

Your thesis must contain a suitable Bibliography which lists all the sources used or consulted on developing the work. The list of references is placed at the end of the manuscript after the chapter containing the conclusions. We suggest using *Mendeley* integrated in Word.

*Here is how you cite bibliography entries: [2], or multiple ones at once: [3, 5].*

The bibliography and list of references are generated automatically by running *Mendeley.*

# Conclusion and future development

A final chapter containing the main conclusions of your research/study and possible future developments of your work have to be inserted in this chapter.

# Bibliography

[1] D. E. Knuth. Computer programming as an art. *Commun. ACM*, pages 667-673, 1974.

[2] D. E. Knuth.Two notes on notation. *Amer Math, Monthly*, 99:403-422, 1992.

[3] L. Lamport. *LaTeX: A Document Preparation System*. Pearson Education India, 1994.

[4] URL <https://ctan.org/topic/bibtex-doc>.

[5] T. Oetiker, H. Partl, I. Hyna, and E. Schlegl. The not so short introduction to latex2. *Electronic document available at http://www. tex. ac. uk/tex-archive/info/lshort, 1995.*

# Appendix A

If you need to include an appendix to support the research in your thesis, you can place it at the end of the manuscript. An appendix contains supplementary material (figures, tables, data, codes, mathematical proofs, surveys, …) which supplement the main results contained in the previous chapters.

# Appendix B

It may be necessary to include another appendix to better organize the presentation of supplementary material.

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[Table 1.3: Highlighting the rows. 6](#_Toc74903741)

# List of Symbols

|  |  |  |
| --- | --- | --- |
| **Variable** | **Description** | **SI unit** |
| ***u*** | solid displacement | m |
| ***uf*** | fluid displacement | m |

# Acknowledgements

Here you might want to acknowledge someone.