



Electrical, Electromagnetic, and Optical Characterization of the InP/InGaAs Alloy System

A Thesis
Presented to the Faculty of the
Department of Electronics and Communications Engineering
Gokongwei College of Engineering
De La Salle University

In Partial Fulfillment of the
Requirements for the Degree of
Bachelor of Science in Electronics and Communications Engineering

by
DELA CRUZ, Juan Z.
FRANCO, Nat Y.
GARCIA, Sebastian X.
MARTINEZ, Isabella W.
RIANZARES, Max V.

July, 2018



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THESIS PROPOSAL APPROVAL SHEET

SAMPLE ONLY

This thesis proposal entitled **Electrical, Electromagnetic, and Optical Characterization of the InP/InGaAs Alloy System**, prepared and submitted by:

DELA CRUZ, Juan Z.
FRANCO, Nat Y.
GARCIA, Sebastian X.
MARTINEZ, Isabella W.
RIANZARES, Max V.

with group number ESG-04 in partial fulfillment of the requirements for the degree of **Bachelor of Science in Electronics and Communications Engineering (BS-ECE)** has been examined and is recommended for acceptance and approval.

PANEL OF EXAMINERS

Dr. Amado Z. Hernandez
Chair

Dr. Jose Y. Alonzo
Member

Dr. Mariana X. Mercado
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Dr. Francisco D. Baltasar
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Suggestions for choosing the title of your document: The **title** must be reflective of its problem. Use the following checklist to help you in making the title.

- ☐ **WHAT** question: Will answer the following
 - ☐ Did you put what you are trying to investigate?
 - ☐ Did you indicate what you are trying to find out, determine or discover?
- ☐ **WHO** question: Will answer who are the respondents or subjects of the study
- ☐ **WHERE** question: Will indicate the research locale, setting or the place where the research study is conducted or where it can be applied.

2018

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ACKNOWLEDGMENT

Write this prior to binding your thesis if you have submitted necessary requirements and are told by the university that you have passed.



ABSTRACT

Keep your abstract short by giving the gist/nutshell of your thesis. Use the following checklist questions to help you in crafting your abstract.

- ☐ Did you briefly state what you intend to do?
- ☐ Did you concisely discuss the problem statement?
- ☐ Did you tersely mention the objectives in general terms?
- ☐ Did you succinctly describe the methodology for the target audience?
- ☐ Did you strongly describe your significant results and your conclusions?

Index Terms—alloy system, characterization, InP, InGaAs.



TABLE OF CONTENTS

Thesis Approval Sheet	ii
Acknowledgment	iv
Abstract	v
Table of Contents	vi
List of Figures	ix
List of Tables	x
Abbreviations	xi
Notation	xii
Glossary	xiii
Listings	xiv
Chapter 1 INTRODUCTION	1
1.1 Background of the Study	2
1.2 Prior Studies	5
1.3 Problem Statement	6
1.4 Objectives	7
1.4.1 General Objective(s)	7
1.4.2 Specific Objectives	7
1.5 Significance of the Study	8
1.6 Assumptions, Scope and Delimitations	8
1.6.1 Assumptions	8
1.6.2 Scope	9
1.6.3 Delimitations	9
1.7 Description and Methodology of the Thesis	9
1.8 Overview of the Thesis	10
Chapter 2 LITERATURE REVIEW	11
2.1 Existing Work	12



2.2	Lacking in the Approaches	14
2.3	Summary	16
Chapter 3	THEORETICAL CONSIDERATIONS	17
3.1	Summary	20
Chapter 4	DESIGN CONSIDERATIONS	21
4.1	Summary	24
Chapter 5	METHODOLOGY	25
5.1	Implementation	26
5.2	Evaluation	28
5.3	Summary	31
Chapter 6	RESULTS AND DISCUSSIONS	32
6.1	Summary	35
Chapter 7	CONCLUSIONS, RECOMMENDATIONS, AND FUTURE DIREC- TIVES	36
7.1	Concluding Remarks	37
7.2	Contributions	37
7.3	Recommendations	37
7.4	Future Prospects	39
References		41
Appendix A	STUDENT RESEARCH ETHICS CLEARANCE	50
Appendix B	ANSWERS TO QUESTIONS TO THIS THESIS	52
Appendix C	REVISIONS TO THE PROPOSAL	61
Appendix D	REVISIONS TO THE FINAL	67
Appendix E	USAGE EXAMPLES	73
E1	Equations	74
E2	Notations	76
E2.1	Math alphabets	76
E2.2	Vector symbols	76
E2.3	Matrix symbols	76
E2.4	Tensor symbols	77



E2.5	Bold math version	78
E2.5.1	Vector symbols	78
E2.5.2	Matrix symbols	78
E2.5.3	Tensor symbols	78
E3	Abbreviation	82
E4	Glossary	84
E5	Figure	86
E6	Table	92
E7	Algorithm or Pseudocode Listing	96
E8	Program/Code Listing	98
E9	Referencing	100
E9.1	A subsection	101
E9.1.1	A sub-subsection	102
E10	Citing	103
E10.1	Books	103
E10.2	Booklets	105
E10.3	Proceedings	105
E10.4	In books	105
E10.5	In proceedings	106
E10.6	Journals	106
E10.7	Theses/dissertations	108
E10.8	Technical Reports and Others	108
E10.9	Miscellaneous	109
E11	Index	110
E12	Adding Relevant PDF Pages	111
Appendix F VITA		115



LIST OF FIGURES

3.1	A quadrilateral image example.	20
E.1	A quadrilateral image example.	86
E.2	Figures on top of each other. See List. E.6 for the corresponding \LaTeX code.	88
E.3	Four figures in each corner. See List. E.7 for the corresponding \LaTeX code. .	90



LIST OF TABLES

C.1	Summary of Revisions to the Proposal	62
D.1	Summary of Revisions to the Thesis	68
E.1	Feasible triples for highly variable grid	92
E.2	Calculation of $y = x^n$	96



ABBREVIATIONS

AC	Alternating Current.....	82
HTML	Hyper-text Markup Language	82
CSS	Cascading Style Sheet	82
XML	eXtensible Markup Language	82



NOTATION

\mathcal{S}	a collection of distinct objects	84
\mathcal{U}	the set containing everything	84
\emptyset	the set with no elements	84
$ \mathcal{S} $	the number of elements in the set \mathcal{S}	84
$h(t)$	impulse response	74
$x(t)$	input signal represented in the time domain	74
$y(t)$	output signal represented in the time domain	74

Throughout this thesis, mathematical notations conform to ISO 80000-2 standard, e.g. variable names are printed in italics, the only exception being acronyms like e.g. SNR, which are printed in regular font. Constants are also set in regular font like j . Functions are also set in regular font, e.g. in $\sin(\cdot)$. Commonly used notations are t , f , $j = \sqrt{-1}$, n and $\exp(\cdot)$, which refer to the time variable, frequency variable, imaginary unit, n th variable, and exponential function, respectively.



GLOSSARY

matrix

a concise and useful way of uniquely representing and working with linear transformations; a rectangular table of elements

Functional Analysis

the branch of Mathematics concerned with the study of spaces of functions



LISTINGS

E.1	Sample \LaTeX code for equations and notations usage	75
E.2	Sample \LaTeX code for notations usage	79
E.3	Sample \LaTeX code for abbreviations usage	83
E.4	Sample \LaTeX code for glossary and notations usage	85
E.5	Sample \LaTeX code for a single figure	87
E.6	Sample \LaTeX code for three figures on top of each other	89
E.7	Sample \LaTeX code for the four figures	91
E.8	Sample \LaTeX code for making typical table environment	94
E.9	Sample \LaTeX code for algorithm or pseudocode listing usage	97
E.10	Computing Fibonacci numbers	98
E.11	Sample \LaTeX code for program listing	99
E.12	Sample \LaTeX code for referencing sections	100
E.13	Sample \LaTeX code for referencing subsections	101
E.14	Sample \LaTeX code for referencing sub-subsections	102
E.15	Sample \LaTeX code for Index usage	110
E.16	Sample \LaTeX code for including PDF pages	111



Chapter 1

INTRODUCTION

Contents

1.1	Background of the Study	2
1.2	Prior Studies	5
1.3	Problem Statement	6
1.4	Objectives	7
1.4.1	General Objective(s)	7
1.4.2	Specific Objectives	7
1.5	Significance of the Study	8
1.6	Assumptions, Scope and Delimitations	8
1.6.1	Assumptions	8
1.6.2	Scope	9
1.6.3	Delimitations	9
1.7	Description and Methodology of the Thesis	9
1.8	Overview of the Thesis	10



1.1 Background of the Study

A quadrotor or a quadcopter is a small mechanical vehicle that can fly using four propellers that are run by motors. These machines have been around from quite some time actually as early as the 1920s and 1930s (droneomega.com). However, these early concepts had bad performance and were very large that caused its instability (droneomega.com). Through the years, quadcopters have improved due to the advancement of technology and recently they have been gaining popularity due to its impressive capabilities (Brown, 2016). Today, drones are working in so many areas that these may be the future of humanity.

Quadrotors (or quadcopters) find uses in a large variety of applications ranging from photography to military uses. They're used in the entertainment industry for wide-angle shots from high altitudes, used as mounts for cameras in many styles of photography, and are used to get shots in dangerous situations. (Brown, 2017). These are great for capturing scenes from angles that were impossible before. Quadrotors are also applied in military and law enforcement as unmanned surveillance devices. They can act as scouts in missions to perform reconnaissance without the need of putting a human life in danger of the unknown. These types of drones also find a lot of use in human rescue, as their high-mobility allows rescuers to quickly and efficiently survey areas of disaster for any potential survivors. It can also be used to drop medicines and supplies to unreachable locations (Riche, 2017). They also find uses in the field of agriculture, keeping track of crops through remote cameras and taking advantage of its speed to study large sized farm lands quickly.

All of these applications are however are drawn back by the short flight times of commercially available drones. High-end quadrotor drones can stay in continuous flight for up to 20 minutes at a time before recharging is required. A primary benefit from this study



would be a general improvement to battery life for all applications of quadrotors, as most of these applications would greatly benefit from an increase to flight-time.

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1.2 Prior Studies

Put here a narrative and a summary (not a duplicate) of your literature review chapter. In this section, summarize and highlight the gap(s) found in the literature review in Chapter 2. Preferably, a table showing the summary would be helpful.

Prior Studies or Literature Review¹ (expansion of the Prior Studies) is basically about **competition**. **Competition**.

So the suggested goals in writing the narrative of the Prior Studies in summative and highlighted forms are, in no particular order:

1. to mention briefly the problem;
2. to show the features of the existing literature in solving the problem
3. to show the weaknesses of the solutions of existing literature
4. to show how your solution is better (can be better (for proposals))

If the suggested table will be placed, please discuss it in light of the above-mentioned items.

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¹The main difference between the Prior Studies and Literature Review is that the Prior Studies is done in a concise manner. By the way, this is also an example of a footnote usage.



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1.3 Problem Statement

From the thesis “Development of a Remote-Controlled Quadrotor with Solar Recharging and Emergency Landing Capabilities” by Lachicha, Jr., et. al, they have successfully increased the battery life of their quadrotor by attaching solar panels that is able to charge their batteries while having a switch between the two batteries that could automatically use the other battery when 11.1 volts is reached without affecting the flight. They were able to increase the flight time of their quadrotor by 1.25 times compared to its original record with successful emergency landing when batteries are low without harming the quadrotor and batteries.

Even with high success rates of the project, our group would improve their project by following one of their recommendations to have a lighter weight for the quadrotor; They have suggested to use carbon fiber materials and balsa woods. In addition to their recommendation, the researchers will replace the used gizduino to PIC, wherein the latter is lighter in comparison; Also, the researchers would decrease the size of the frames. Smaller frame would lessen the amount of solar panels but to compensate, we will be adding a voltage regulator and amplifiers that is lightweight for better power management thus being able to prolong the battery life.

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1.4 Objectives

Your objectives are the states that you desire to achieve in solving the problem. The general objective is the main state to be achieved whereas the specific ones are sub-states to be achieved.

1.4.1 General Objective(s)

To ...;

1.4.2 Specific Objectives

1. To ...;
2. To ...;
3. To ...;
4. To ...;
5. To ...;



1.5 Significance of the Study

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1.6 Assumptions, Scope and Delimitations

Bulletize your assumptions in one group, and then bulletize the scope in another, and do the same for your delimitations. The assumptions to put here are those major facts or statements that are *key* for your proposed solution to work. Scope refers to the space(s) for the operation of your proposed solution, whereas delimitations are the limits of the operation of your proposed solution.

1.6.1 Assumptions

1. ...;
2. ...;
3. ...;



1.6.2 Scope

1. ...;
2. ...;
3. ...;

1.6.3 Delimitations

1. ...;
2. ...;
3. ...;

1.7 Description and Methodology of the Thesis

A purpose of the description here is to re-steer/remind the panelist/reader again by tersely describing what your thesis is about (i.e. the problem and the main goal you want to achieve) in another way without sounding repetitive.

Your methodology is your means of achieving your stated objectives.

Note that each stated objective should have a corresponding methodology of achieving it.

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1.8 Overview of the Thesis

Provide here a brief summary and what the reader should expect from each succeeding chapter. Show how each chapter is connected with each other.



Chapter 2

LITERATURE REVIEW

Contents

2.1	Existing Work	12
2.2	Lacking in the Approaches	14
2.3	Summary	16



It is to be noted that each subsection in this chapter should discuss in narrative form each table that is presented.

2.1 Existing Work

Cite and summarize here relevant and significant literature (dissertations, theses, journals, patents, notable conference papers) through a table and descriptions to prove that no one has done your work yet and/or that your work is not a duplication of existing ones. Your focus here is what has *been done*.

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2.2 Lacking in the Approaches

You can summarize the weaknesses of existing approaches by a tabular comparison of the literature. Your focus here is what has *not been done*, i.e. what features were missed, what solutions were not considered, what the demerits are, etc. Through these items, you then can introduce the necessity for doing your proposed solution.

It is to be noted that degree of novelty for undergraduate thesis is lower than those for graduate school. If a PhD dissertation/thesis has a high degree of novelty and that for an undergraduate is low, then a master's thesis is somewhere between the two.

Briefly include here the following in order to remind the reader why you are highlighting the weaknesses of the solutions of existing literature.

- mentioning of the problem
- showing how your solution is better (can be better (for proposals))

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2.3 Summary

Provide the gist of this chapter such that it reflects the contents and the message.



Chapter 3

THEORETICAL CONSIDERATIONS

Contents

3.1 Summary	20
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Before starting the first section, provide an overview of the purpose of this chapter and its contents, and how they are relevant to your methodology. Discuss in this chapter the relevant theories and concepts that should support your proposed solutions.

This chapter is for providing the context to your panelist/reader. It is actually an expanded form of the Background of the Study that you have put in Chapter 1.

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Fig. 3.1 A quadrilateral image example.

3.1 Summary

Provide the gist of this chapter such that it reflects the contents and the message.



Chapter 4

DESIGN CONSIDERATIONS

Contents

4.1 Summary	24
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Before starting the first section, provide an overview of the purpose of this chapter and its contents, and how they are relevant to your methodology.

Your primary goal in the Design Considerations chapter is to describe to your panelist/readers the key topics that fall further under Theoretical Considerations, but should be placed here instead since they are geared towards your Methodology. These key topics are those that you have directly adopted in making your solution/methodology. You can think of the connection of the Design Considerations chapter to the Theoretical Considerations chapter in this way: if your Theoretical Considerations chapter serves as the main foundation of a building, then the Design Considerations chapter functions as the columns.

The Design Considerations chapter is an avenue for explaining why you considered the topics here for your proposed methodology. This chapter is different from your methodology, because topics you discuss here are already accepted as part of the body of knowledge, and may have not been developed by you.

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4.1 Summary

Provide the gist of this chapter such that it reflects the contents and message.



Chapter 5

METHODOLOGY

Contents

5.1	Implementation	26
5.2	Evaluation	28
5.3	Summary	31



Put an overview of the contents of chapter. Mention here your methodology flow through a figure and provide an overview of it and how your methodology achieves your objectives. How your methodology achieves each of your specific objective is what your panelists/examiners will be looking for. Specify how your methodology achieves your general objective, and specific objectives. A point-by-point comparison how your methodology achieves each of your specific objective is expected in the final Thesis.

Also make sure that you refer clearly to the chapters on the Literature Review, Theoretical Considerations, and Design Considerations showing how your methodology ties with those that you have discussed in those chapters.

Make an overview of the contents of chapter. Put here your methodology flow through a figure and provide an overview of it.

5.1 Implementation

Summarize the process used to create/set-up the work with an explanation of such process, instruments, and materials that you used if any. If the description is lengthy, use condensed bullet points.

Rule of thumb: Implementation is how you made your work; (keywords: implemented, created, made, soldered, programmed, etc.).

If you wrote a program or made a simulation, you must state how the program or simulation functions in this section. An algorithm or a pseudocode as shown in Table E.2 is a good example.

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5.2 Evaluation

Describe the procedures for evaluating the correct behavior and outcome of your work, including what information you need to gather and how you will obtain or measure it.



Rule of thumb: Evaluation is how you tested your work; (keywords: measured, tested, compared, simulated, etc.).

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5.3 Summary

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Chapter 6

RESULTS AND DISCUSSIONS

Contents

6.1 Summary	35
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Show in this chapter proofs why your proposed solution works. However, presenting results ("It worked") without an appropriate explanation does not show thorough understanding. Aside from the data and results that you have obtained, and their explanation, the discussion includes why components of your proposed solution work did or did not work in accordance to what you described in the evaluation process, and how the proposed solution performed and faired. Interpret the results and the reasons why they were obtained. If your results are incorrect, apparent discrepancies from theory should be pointed out and explained. In essence, what do the results mean. Citing existing publication can help you compare your results and your explanations.

The next items below is not related to the description of this results and discussions chapter, but serves as an opener for the \LaTeX portion of this template.

Here is an example of a citation for ISO 80000-2 standard [ISO, 2009]. Another one is [Einstein, 1905] and [Croft, 1978].

In using this template, the user is expected to have a working knowledge of \LaTeX . A good introduction is in [Oetiker et al., 2014]. Its latest version can be accessed at <http://www.ctan.org/tex-archive/info/lshort>. See the Appendix of `document_guide.pdf` for examples.

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6.1 Summary

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Chapter 7

CONCLUSIONS, RECOMMENDATIONS, AND FUTURE DIRECTIVES

Contents

7.1	Concluding Remarks	37
7.2	Contributions	37
7.3	Recommendations	37
7.4	Future Prospects	39



7.1 Concluding Remarks

In this Thesis, . . .

Put here the main points that should be known and learned about the work topic. Summarize or give the gist of the essential principles and inferences drawn from your results.

7.2 Contributions

The interrelated contributions and supplements that have been developed by the author(s) in this Thesis are listed as follows. Only those that are unique to the authors' work are included.

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7.3 Recommendations

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7. Conclusions, Recommendations, and Future Directives



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7.4 Future Prospects

There are several prospect related in this research that may be extended for further studies. ... So the suggested topics are listed in the following.

1. the
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7. Conclusions, Recommendations, and Future Directives



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Note that for ECE undergraduate theses, as per the directions of the thesis adviser, Recommendations and Future Directives will be removed for the hardbound copy but will be retained for database storage.



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De La Salle University

Appendix A
STUDENT RESEARCH ETHICS
CLEARANCE


RESEARCH ETHICS CLEARANCE FORM¹
For Thesis Proposals

Names of Student Researcher(s):

Dela Cruz, Juan Z.

College: **Gokongwei College of Engineering**Department: **Electronics and Communications Engineering**Course: **PhD-ECE**Expected Duration of the Project: from: **April 2015**to: **April 2017**

Ethical considerations

None

(The [Ethics Checklists](#) may be used as guides in determining areas for ethical concern/consideration)

To the best of my knowledge, the ethical issues listed above have been addressed in the research.

Dr. Francisco D. Baltasar

Name and Signature of Adviser/Mentor:

Date: **April 8, 2017**

Noted by:

Dr. Rafael W. Sison

Name and Signature of the Department Chairperson:

Date: **April 8, 2017**

¹ The same form can be used for the reports of completed projects. The appropriate heading need only be used.



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Appendix B
ANSWERS TO QUESTIONS TO THIS
THESIS



B1 How important is the problem to practice?

A possible answer to this question is the summary of your Significance of the Study, and that portion of the Problem Statement where you describe the ideal scenario for your intended audience.

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B2 How will you know if the solution/s that you will achieve would be better than existing ones?

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B2.1 How will you measure the improvement/s?

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B2.1.1 What is/are your basis/bases for the improvement/s?

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B2.1.2 Why did you choose that/those basis/bases?

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B2.1.3 How significant are your measure/s of the improvement/s?

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B3 What is the difference of the solution/s from existing ones?

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B3.1 How is it different from previous and existing ones?

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B4 What are the assumptions made (that are behind for your proposed solution to work)?

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B4.1 Will your proposed solution/s be sensitive to these assumptions?

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B4.2 Can your proposed solution/s be applied to more general cases when some of the assumptions are eliminated? If so, how?

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B5 What is the necessity of your approach / proposed solution/s?

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B5.1 What will be the limits of applicability of your proposed solution/s?

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B5.2 What will be the message of the proposed solution to technical people? How about to non-technical managers and business men?

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B6 How will you know if your proposed solution/s is/are correct?

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B6.1 Will your results warrant the level of mathematics used (i.e., will the end justify the means)?

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B7 Is/are there an/_ alternative way/s to get to the same solution/s?

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B7.1 Can you come up with illustrating examples, or even better, counter examples to your proposed solution/s?

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Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris. Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit amet ipsum. Nunc quis urna dictum turpis accumsan semper.

B7.2 Is there an approximation that can arrive at the essentially the same proposed solution/s more easily?

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B8 If you were the examiner of your Thesis, how would you present the Thesis in another way? Give your remarks, especially for your methodology and the results and discussions.

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**B8.1 What are the weaknesses of your Thesis, specifically your methodology and the results and discussions?**

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De La Salle University

Appendix C

REVISIONS TO THE PROPOSAL



Make a table with the following columns for showing the summary of revisions to the proposal based on the comments of the panel of examiners.

1. Panelist name
2. Comment
3. Summary of how the comment was addressed
4. Locations in the document where the changes have been reflected

TABLE C.1 SUMMARY OF REVISIONS TO THE PROPOSAL

Panelist name	Comment	Summary of how the comment was addressed	Locations
Dr. Francisco D. Baltasar	<p>Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem. Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor. Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris. Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit amet ipsum. Nunc quis urna dictum turpis accumsan semper.</p>	<p>Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem. Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor. Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris. Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit amet ipsum. Nunc quis urna dictum turpis accumsan semper.</p> <p>First itemtext</p> <p>Second itemtext</p> <p>Last itemtext</p> <p>First itemtext</p> <p>Second itemtext</p>	<p>Sec. 5.1 on p. 26, Sec. 5.2 on p. 28, Fig. 3.1 on p. 20</p>

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Panelist name	Comment	Summary of how the comment was addressed	Locations
Dr. Amado Z. Hernandez	<p>Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem. Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor. Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris. Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit amet ipsum. Nunc quis urna dictum turpis accumsan semper.</p>	<p>Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem. Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor. Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris. Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit amet ipsum. Nunc quis urna dictum turpis accumsan semper.</p> <p>First itemtext</p> <p>Second itemtext</p> <p>Last itemtext</p> <p>First itemtext</p> <p>Second itemtext</p>	<p>Sec. 5.1 on p. 26, Sec. 5.2 on p. 28, Fig. 3.1 on p. 20</p>

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Panelist name	Comment	Summary of how the comment was addressed	Locations
Dr. Jose Y. Alonzo	<p>Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem. Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor. Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris. Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit amet ipsum. Nunc quis urna dictum turpis accumsan semper.</p>	<p>Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem. Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor. Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris. Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit amet ipsum. Nunc quis urna dictum turpis accumsan semper.</p> <ul style="list-style-type: none"> • First itemtext • Second itemtext • Last itemtext • First itemtext • Second itemtext 	<p>Sec. 5.1 on p. 26, Sec. 5.2 on p. 28, Fig. 3.1 on p. 20</p>

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Panelist name	Comment	Summary of how the comment was addressed	Locations
Dr. Mariana X. Mercado	<p>Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem. Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor. Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris. Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit amet ipsum. Nunc quis urna dictum turpis accumsan semper.</p>	<p>Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem. Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor. Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris. Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit amet ipsum. Nunc quis urna dictum turpis accumsan semper.</p> <ol style="list-style-type: none"> 1. First itemtext 2. Second itemtext 3. Last itemtext 4. First itemtext 5. Second itemtext 	<p>Sec. 5.1 on p. 26, Sec. 5.2 on p. 28, Fig. 3.1 on p. 20</p>

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Panelist name	Comment	Summary of how the comment was addressed	Locations
Dr. Rafael W. Sison	<p>Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem. Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor. Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris. Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit amet ipsum. Nunc quis urna dictum turpis accumsan semper.</p>	<p>Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem. Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor. Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris. Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit amet ipsum. Nunc quis urna dictum turpis accumsan semper.</p>	<p>Sec. 5.1 on p. 26, Sec. 5.2 on p. 28, Fig. 3.1 on p. 20</p>



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Appendix D

REVISIONS TO THE FINAL



Make a table with the following columns for showing the summary of revisions to the proposal based on the comments of the panel of examiners.

1. Panelist name
2. Comment
3. Summary of how the comment has been addressed
4. Locations in the document where the changes have been reflected

TABLE D.1 SUMMARY OF REVISIONS TO THE THESIS

Panelist name	Comment	Summary of how the comment has been addressed	Locations
Dr. Francisco D. Baltasar	<p>Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem. Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor. Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris. Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit amet ipsum. Nunc quis urna dictum turpis accumsan semper.</p>	<p>Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem. Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor. Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris. Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit amet ipsum. Nunc quis urna dictum turpis accumsan semper.</p> <p>First itemtext</p> <p>Second itemtext</p> <p>Last itemtext</p> <p>First itemtext</p> <p>Second itemtext</p>	<p>Sec. 5.1 on p. 26, Sec. 5.2 on p. 28, Fig. 3.1 on p. 20</p>

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Panelist name	Comment	Summary of how the comment has been addressed	Locations
Dr. Amado Z. Hernandez	<p>Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem. Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec ullamcorper, felis non sodales commodo, lectus velit ultricies augue, a dignissim nibh lectus placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor. Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris. Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit amet ipsum. Nunc quis urna dictum turpis accumsan semper.</p>	<p>Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem. Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec ullamcorper, felis non sodales commodo, lectus velit ultricies augue, a dignissim nibh lectus placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor. Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris. Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit amet ipsum. Nunc quis urna dictum turpis accumsan semper.</p> <p>First itemtext</p> <p>Second itemtext</p> <p>Last itemtext</p> <p>First itemtext</p> <p>Second itemtext</p>	<p>Sec. 5.1 on p. 26, Sec. 5.2 on p. 28, Fig. 3.1 on p. 20</p>

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Panelist name	Comment	Summary of how the comment has been addressed	Locations
Dr. Jose Y. Alonzo	<p>Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem. Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor. Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris. Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit amet ipsum. Nunc quis urna dictum turpis accumsan semper.</p>	<p>Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem. Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor. Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris. Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit amet ipsum. Nunc quis urna dictum turpis accumsan semper.</p> <ul style="list-style-type: none"> • First itemtext • Second itemtext • Last itemtext • First itemtext • Second itemtext 	<p>Sec. 5.1 on p. 26, Sec. 5.2 on p. 28, Fig. 3.1 on p. 20</p>

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Panelist name	Comment	Summary of how the comment has been addressed	Locations
Dr. Mariana X. Mercado	<p>Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem. Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor. Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris. Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit amet ipsum. Nunc quis urna dictum turpis accumsan semper.</p>	<p>Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem. Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor. Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris. Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit amet ipsum. Nunc quis urna dictum turpis accumsan semper.</p> <ol style="list-style-type: none"> 1. First itemtext 2. Second itemtext 3. Last itemtext 4. First itemtext 5. Second itemtext 	<p>Sec. 5.1 on p. 26, Sec. 5.2 on p. 28, Fig. 3.1 on p. 20</p>

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Continued from previous page

Panelist name	Comment	Summary of how the comment has been addressed	Locations
Dr. Rafael W. Sison	<p>Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem. Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor. Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris. Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit amet ipsum. Nunc quis urna dictum turpis accumsan semper.</p>	<p>Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem. Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor. Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris. Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit amet ipsum. Nunc quis urna dictum turpis accumsan semper.</p>	<p>Sec. 5.1 on p. 26, Sec. 5.2 on p. 28, Fig. 3.1 on p. 20</p>



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Appendix E

USAGE EXAMPLES



The user is expected to have a working knowledge of \LaTeX . A good introduction is in [Oetiker et al., 2014]. Its latest version can be accessed at <http://www.ctan.org/tex-archive/info/lshort>.

E1 Equations

The following examples show how to typeset equations in \LaTeX . This section also shows examples of the use of `\gls{ }` commands in conjunction with the items that are in the `notation.tex` file. **Please make sure that the entries in `notation.tex` are those that are referenced in the \LaTeX document files used by this Thesis. Please comment out unused notations and be careful with the commas and brackets in `notation.tex`.**

In (E.1), the output signal $y(t)$ is the result of the convolution of the input signal $x(t)$ and the impulse response $h(t)$.

$$y(t) = h(t) * x(t) = \int_{-\infty}^{+\infty} h(t - \tau) x(\tau) d\tau \quad (\text{E.1})$$

Other example equations are as follows.

$$\begin{bmatrix} V_1 \\ I_1 \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} V_2 \\ I_2 \end{bmatrix} \quad (\text{E.2})$$

$$\frac{1}{2} < \left[\text{mod} \left(\left\lfloor \frac{y}{17} \right\rfloor 2^{-17\lfloor x \rfloor - \text{mod}(\lfloor y \rfloor, 17)}, 2 \right) \right], \quad (\text{E.3})$$

$$|\zeta(x)^3 \zeta(x + iy)^4 \zeta(x + 2iy)| = \exp \sum_{n,p} \frac{3 + 4 \cos(ny \log p) + \cos(2ny \log p)}{np^{nx}} \geq 1 \quad (\text{E.4})$$



The verbatim \LaTeX code of Sec. E1 is in List. E.1.

Listing E.1: Sample \LaTeX code for equations and notations usage

```

1 The following examples show how to typeset equations in \LaTeX. This
  section also shows examples of the use of \verb| \gls{ } | commands
  in conjunction with the items that are in the \verb| notation.tex |
  file. \textbf{Please make sure that the entries in} \verb| notation.
  tex | \textbf{are those that are referenced in the} \LaTeX \
  document files used by this \documentType. Please comment out
  unused notations and be careful with the commas and brackets in} \
  \verb| notation.tex |.

2
3 In~\eqref{eq:conv}, the output signal \gls{not:output_sigt} is the
  result of the convolution of the input signal \gls{not:input_sigt}
  and the impulse response \gls{not:ir}.

4
5 \begin{eqnarray}
6   y\left( t \right) = h\left( t \right) * x\left( t \right)=\int_{-\infty}^{+\infty}h\left( t-\tau \right)x\left( \tau \right) \mathrm{d}\tau
7   \label{eq:conv}
8 \end{eqnarray}
9
10 Other example equations are as follows.
11
12 \begin{eqnarray}
13   \left[ \begin{matrix} V_{1} \\ I_{1} \end{matrix} \right] = \\
14   \begin{matrix} A & B \\ C & D \end{matrix} \\
15   \left[ \begin{matrix} V_{2} \\ I_{2} \end{matrix} \right] \\
16   \label{eq:ABCD}
17 \end{eqnarray}
18
19 \begin{eqnarray}
20   \left[ \begin{matrix} V_{1} \\ I_{1} \end{matrix} \right] = \left[ \begin{matrix} A & B \\ C & D \end{matrix} \right] \left[ \begin{matrix} V_{2} \\ I_{2} \end{matrix} \right]
21   \label{eq:ABCD}
22 \end{eqnarray}
23
24 \begin{eqnarray}
25   \left[ \begin{matrix} V_{1} \\ I_{1} \end{matrix} \right] = \left[ \begin{matrix} A & B \\ C & D \end{matrix} \right] \left[ \begin{matrix} V_{2} \\ I_{2} \end{matrix} \right]
26   \label{eq:ABCD}
27 \end{eqnarray}
28
29 \begin{eqnarray}
30   \left[ \begin{matrix} V_{1} \\ I_{1} \end{matrix} \right] = \left[ \begin{matrix} A & B \\ C & D \end{matrix} \right] \left[ \begin{matrix} V_{2} \\ I_{2} \end{matrix} \right]
31   \label{eq:ABCD}
32 \end{eqnarray}

```



E2 Notations

In order to use the standardized notation, the user is highly suggested to see the ISO 80000-2 standard [ISO, 2009].

See https://en.wikipedia.org/wiki/Help:Displaying_a_formula and https://en.wikipedia.org/wiki/List_of_mathematical_symbols for L^AT_EX maths and other notations, respectively.

The following were taken from `isomath-test.tex`.

E2.1 Math alphabets

If there are other symbols in place of Greek letters in a math alphabet, it uses T1 or OT1 font encoding instead of OML.

<code>mathnormal</code>	$A, B, \Gamma, \Delta, \Theta, \Lambda, \Xi, \Pi, \Sigma, \Phi, \Psi, \Omega, \alpha, \beta, \pi, \nu, \omega, v, w, 0, 1, 9$
<code>mathit</code>	$A, B, \Gamma, \Delta, \Theta, \Lambda, \Xi, \Pi, \Sigma, \Phi, \Psi, \Omega, \mathfrak{f}, \mathfrak{f}, \beta, \circ, !, v, w, 0, 1, 9$
<code>mathrm</code>	$A, B, \Gamma, \Delta, \Theta, \Lambda, \Xi, \Pi, \Sigma, \Phi, \Psi, \Omega, \mathfrak{f}, \mathfrak{f}, \beta, \circ, !, v, w, 0, 1, 9$
<code>mathbf</code>	$\mathbf{A}, \mathbf{B}, \mathbf{\Gamma}, \mathbf{\Delta}, \mathbf{\Theta}, \mathbf{\Lambda}, \mathbf{\Xi}, \mathbf{\Pi}, \mathbf{\Sigma}, \mathbf{\Phi}, \mathbf{\Psi}, \mathbf{\Omega}, \mathbf{f}, \mathbf{f}, \mathbf{\beta}, \circ, !, v, w, 0, 1, 9$
<code>mathsf</code>	$A, B, \Gamma, \Delta, \Theta, \Lambda, \Xi, \Pi, \Sigma, \Phi, \Psi, \Omega, \mathfrak{f}, \mathfrak{f}, \beta, \circ, !, v, w, 0, 1, 9$
<code>mathtt</code>	$A, B, \Gamma, \Delta, \Theta, \Lambda, \Xi, \Pi, \Sigma, \Phi, \Psi, \Omega, \uparrow, \downarrow, \beta, \circ, !, v, w, 0, 1, 9$

New alphabets bold-italic, sans-serif-italic, and sans-serif-bold-italic.

<code>mathbfit</code>	$\mathbf{A}, \mathbf{B}, \mathbf{\Gamma}, \mathbf{\Delta}, \mathbf{\Theta}, \mathbf{\Lambda}, \mathbf{\Xi}, \mathbf{\Pi}, \mathbf{\Sigma}, \mathbf{\Phi}, \mathbf{\Psi}, \mathbf{\Omega}, \alpha, \beta, \pi, \nu, \omega, v, w, 0, 1, 9$
<code>mathsf</code>	$A, B, \Gamma, \Delta, \Theta, \Lambda, \Xi, \Pi, \Sigma, \Phi, \Psi, \Omega, \alpha, \beta, \pi, \nu, \omega, v, w, 0, 1, 9$
<code>mathsfbf</code>	$\mathbf{A}, \mathbf{B}, \mathbf{\Gamma}, \mathbf{\Delta}, \mathbf{\Theta}, \mathbf{\Lambda}, \mathbf{\Xi}, \mathbf{\Pi}, \mathbf{\Sigma}, \mathbf{\Phi}, \mathbf{\Psi}, \mathbf{\Omega}, \alpha, \beta, \pi, \nu, \omega, v, w, 0, 1, 9$

Do the math alphabets match?

$\alpha x \alpha \omega \alpha x \alpha \omega \alpha x \alpha \omega \quad T C \Theta \Gamma T C \Theta \Gamma T C \Theta \Gamma$

E2.2 Vector symbols

Alphabetic symbols for vectors are boldface italic, $\lambda = e_1 \cdot \mathbf{a}$, while numeric ones (e.g. the zero vector) are bold upright, $\mathbf{a} + \mathbf{0} = \mathbf{a}$.

E2.3 Matrix symbols

Symbols for matrices are boldface italic, too:¹ $\mathbf{A} = \mathbf{E} \cdot \mathbf{A}$.

¹However, matrix symbols are usually capital letters whereas vectors are small ones. Exceptions are physical quantities like the force vector \mathbf{F} or the electrical field \mathbf{E} .



E2.4 Tensor symbols

Symbols for tensors are sans-serif bold italic,

$$\boldsymbol{\alpha} = \boldsymbol{e} \cdot \boldsymbol{a} \quad \Longleftrightarrow \quad \alpha_{ijl} = e_{ijk} \cdot a_{kl}.$$

The permittivity tensor describes the coupling of electric field and displacement:

$$\boldsymbol{D} = \epsilon_0 \boldsymbol{\epsilon}_r \boldsymbol{E}$$



E2.5 Bold math version

The “bold” math version is selected with the commands `\boldmath` or `\mathversion{bold}`

<code>mathnormal</code>	$A, B, \Gamma, \Delta, \Theta, \Lambda, \Xi, \Pi, \Sigma, \Phi, \Psi, \Omega, \alpha, \beta, \pi, \nu, \omega, v, w, 0, 1, 9$
<code>mathit</code>	$A, B, \Gamma, \Delta, \Theta, \Lambda, \Xi, \Pi, \Sigma, \Phi, \Psi, \Omega, \textit{ff}, \textit{fi}, \beta, \circ, !, v, w, 0, 1, 9$
<code>mathrm</code>	$A, B, \Gamma, \Delta, \Theta, \Lambda, \Xi, \Pi, \Sigma, \Phi, \Psi, \Omega, \text{ff}, \text{fi}, \beta, \circ, !, v, w, 0, 1, 9$
<code>mathbf</code>	$A, B, \Gamma, \Delta, \Theta, \Lambda, \Xi, \Pi, \Sigma, \Phi, \Psi, \Omega, \text{ff}, \text{fi}, \beta, \circ, !, v, w, 0, 1, 9$
<code>mathsf</code>	$\mathbf{A}, \mathbf{B}, \mathbf{\Gamma}, \mathbf{\Delta}, \mathbf{\Theta}, \mathbf{\Lambda}, \mathbf{\Xi}, \mathbf{\Pi}, \mathbf{\Sigma}, \mathbf{\Phi}, \mathbf{\Psi}, \mathbf{\Omega}, \text{ff}, \text{fi}, \beta, \circ, !, v, w, 0, 1, 9$
<code>mathtt</code>	$A, B, \Gamma, \Delta, \Theta, \Lambda, \Xi, \Pi, \Sigma, \Phi, \Psi, \Omega, \uparrow, \downarrow, \beta, \circ, !, v, w, 0, 1, 9$

New alphabets bold-italic, sans-serif-italic, and sans-serif-bold-italic.

<code>mathbfit</code>	$A, B, \Gamma, \Delta, \Theta, \Lambda, \Xi, \Pi, \Sigma, \Phi, \Psi, \Omega, \alpha, \beta, \pi, \nu, \omega, v, w, 0, 1, 9$
<code>mathsfit</code>	$A, B, \Gamma, \Delta, \Theta, \Lambda, \Xi, \Pi, \Sigma, \Phi, \Psi, \Omega, \alpha, \beta, \pi, \nu, \omega, v, w, 0, 1, 9$
<code>mathsfbfit</code>	$A, B, \Gamma, \Delta, \Theta, \Lambda, \Xi, \Pi, \Sigma, \Phi, \Psi, \Omega, \alpha, \beta, \pi, \nu, \omega, v, w, 0, 1, 9$

Do the math alphabets match?

$\alpha x \alpha \omega a x \alpha \omega a x \alpha \omega \quad TC\Theta\Gamma TC\Theta\Gamma TC\Theta\Gamma$

E2.5.1 Vector symbols

Alphabetic symbols for vectors are boldface italic, $\lambda = e_1 \cdot a$, while numeric ones (e.g. the zero vector) are bold upright, $a + 0 = a$.

E2.5.2 Matrix symbols

Symbols for matrices are boldface italic, too:² $\Lambda = E \cdot A$.

E2.5.3 Tensor symbols

Symbols for tensors are sans-serif bold italic,

$$\alpha = e \cdot a \iff \alpha_{ijl} = e_{ijk} \cdot a_{kl}.$$

The permittivity tensor describes the coupling of electric field and displacement:

$$D = \epsilon_0 \epsilon_r E$$

²However, matrix symbols are usually capital letters whereas vectors are small ones. Exceptions are physical quantities like the force vector F or the electrical field E .



The verbatim \LaTeX code of Sec. E2 is in List. E.2.

Listing E.2: Sample \LaTeX code for notations usage

```

1 % A teststring with Latin and Greek letters::
2 \newcommand{\teststring}{%
3 % capital Latin letters
4 % A,B,C,
5 A,B,
6 % capital Greek letters
7 %\Gamma,\Delta,\Theta,\Lambda,\Xi,\Pi,\Sigma,\Upsilon,\Phi,\Psi,
8 \Gamma,\Delta,\Theta,\Lambda,\Xi,\Pi,\Sigma,\Phi,\Psi,\Omega,
9 % small Greek letters
10 \alpha,\beta,\pi,\nu,\omega,
11 % small Latin letters:
12 % compare \nu, \omega, v, and w
13 v,w,
14 % digits
15 0,1,9
16 }
17
18
19 \subsection{Math alphabets}
20
21 If there are other symbols in place of Greek letters in a math
22 alphabet, it uses T1 or OT1 font encoding instead of OML.
23
24 \begin{eqnarray*}
25 \mbox{\mathnormal} & & \mbox{\teststring} \\
26 \mbox{\mathit} & & \mbox{\mathit{\teststring}} \\
27 \mbox{\mathrm} & & \mbox{\mathrm{\teststring}} \\
28 \mbox{\mathbf} & & \mbox{\mathbf{\teststring}} \\
29 \mbox{\mathsf} & & \mbox{\mathsf{\teststring}} \\
30 \mbox{\mathtt} & & \mbox{\mathtt{\teststring}}
31 \end{eqnarray*}
32 New alphabets bold-italic, sans-serif-italic, and sans-serif-bold-
33 italic.
34 \begin{eqnarray*}
35 \mbox{\mathbfit} & & \mbox{\mathbfit{\teststring}} \\
36 \mbox{\mathsfbit} & & \mbox{\mathsfbit{\teststring}} \\
37 \mbox{\mathsfbfit} & & \mbox{\mathsfbfit{\teststring}}
38 \end{eqnarray*}
39 %
40 Do the math alphabets match?
41 $
42 \mathnormal {a x \alpha \omega}
43 \mathbfit {a x \alpha \omega}
44 \mathsfbfit{a x \alpha \omega}
45 \quad
46 \mathsfbfit{T C \Theta \Gamma}
47 \mathbfit {T C \Theta \Gamma}
48 \mathnormal {T C \Theta \Gamma}
49 $
50
51 \subsection{Vector symbols}
52
```



```

53 Alphabetic symbols for vectors are boldface italic,
54  $\vec{\lambda} = \vec{e}_1 \cdot \vec{a}$ ,
55 while numeric ones (e.g. the zero vector) are bold upright,
56  $\vec{a} + \vec{0} = \vec{a}$ .
57
58 \subsection{Matrix symbols}
59
60 Symbols for matrices are boldface italic, too:%
61 \footnote{However, matrix symbols are usually capital letters whereas
62   vectors
63   are small ones. Exceptions are physical quantities like the force
64   vector  $\vec{F}$  or the electrical field  $\vec{E}$ .%
65 }
66  $\Lambda = E \cdot A$ .
67
68 \subsection{Tensor symbols}
69
70 Symbols for tensors are sans-serif bold italic,
71
72 \[
73   \text{\texttt{\textbf{\textit{tensorsym{\alpha}}}}} = \text{\texttt{\textbf{\textit{tensorsym{e}}}}} \cdot \text{\texttt{\textbf{\textit{tensorsym{a}}}}}
74   \quad \Longleftrightarrow \quad
75   \alpha_{ijl} = e_{ijk} \cdot a_{kl}.
76 \]
77
78
79 The permittivity tensor describes the coupling of electric field and
80 displacement: \[
81 \vec{D} = \epsilon_0 \text{\texttt{\textbf{\textit{tensorsym{\epsilon}}}}}_{\text{\texttt{\textbf{\textit{r}}}}} \vec{E} \]
82
83
84
85 \newpage
86 \subsection{Bold math version}
87
88 The ‘‘bold’’ math version is selected with the commands
89 \verb+\boldmath+ or \verb+\mathversion{bold}+
90
91 {\boldmath
92   \begin{eqnarray*}
93     \mbox{\mathnormal} & & \text{\texttt{\textbf{\textit{teststring}}}} \\
94     \mbox{\mathit} & & \text{\texttt{\textbf{\textit{teststring}}}} \\
95     \mbox{\mathrm} & & \text{\texttt{\textbf{\textit{teststring}}}} \\
96     \mbox{\mathbf} & & \text{\texttt{\textbf{\textit{teststring}}}} \\
97     \mbox{\mathsf} & & \text{\texttt{\textbf{\textit{teststring}}}} \\
98     \mbox{\mathtt} & & \text{\texttt{\textbf{\textit{teststring}}}} \\
99   \end{eqnarray*}
100   New alphabets bold-italic, sans-serif-italic, and sans-serif-bold-
101     italic.
102   \begin{eqnarray*}
103     \mbox{\mathbfit} & & \text{\texttt{\textbf{\textit{teststring}}}} \\
104     \mbox{\mathsfit} & & \text{\texttt{\textbf{\textit{teststring}}}} \\
105     \mbox{\mathsfbfit} & & \text{\texttt{\textbf{\textit{teststring}}}} \\
106   \end{eqnarray*}
107   %
108   Do the math alphabets match?

```



```

108 $
109 \mathnormal {a x \alpha \omega}
110 \mathbfit {a x \alpha \omega}
111 \mathsfbfit{a x \alpha \omega}
112 \quad
113 \mathsfbfit{T C \Theta \Gamma}
114 \mathbfit {T C \Theta \Gamma}
115 \mathnormal {T C \Theta \Gamma}
116 $
117
118 \subsection{Vector symbols}
119
120
121 Alphabetic symbols for vectors are boldface italic,
122 $\vec{\lambda}=\vec{e}_{1}\cdot\vec{a}$,
123 while numeric ones (e.g. the zero vector) are bold upright,
124 $\vec{a} + \vec{0} = \vec{a}$.
125
126
127
128
129 \subsection{Matrix symbols}
130
131 Symbols for matrices are boldface italic, too:%
132 \footnote{However, matrix symbols are usually capital letters whereas
133 vectors
134 are small ones. Exceptions are physical quantities like the force
135 vector $\vec{F}$ or the electrical field $\vec{E}$.%
136 }
137 $\matrixsym{\Lambda}=\matrixsym{E}\cdot\matrixsym{A}$.
138
139 \subsection{Tensor symbols}
140
141 Symbols for tensors are sans-serif bold italic,
142
143 \[
144 \quad \matrixsym{\alpha} = \matrixsym{e}\cdot\matrixsym{a}
145 \quad \Longleftrightarrow \quad
146 \quad \alpha_{ijl} = e_{ijk}\cdot a_{kl}.
147 \]
148
149 The permittivity tensor describes the coupling of electric field and
150 displacement: \[
151 \quad \vec{D}=\epsilon_{0}\matrixsym{\epsilon}_{\mathrm{r}}\vec{E}\]
152 }

```



E3 Abbreviation

This section shows examples of the use of \LaTeX commands in conjunction with the items that are in the `abbreviation.tex` and in the `glossary.tex` files. Please see List. E.3. **To lessen the \LaTeX parsing time, it is suggested that you use `\acr{ }` only for the first occurrence of the word to be abbreviated.**

Again please see List. E.3. Here is an example of first use: alternating current (ac). Next use: ac. Full: alternating current (ac). Here's an acronym referenced using `\acr` : hyper-text markup language (html). And here it is again: html. If you are used to the `glossaries` package, note the difference in using `\gls` : hyper-text markup language (html). And again (no difference): hyper-text markup language (html). Here are some more entries:

- extensible markup language (xml) and cascading style sheet (css).
- Next use: xml and css.
- Full form: extensible markup language (xml) and cascading style sheet (css).
- Reset again.
- Start with a capital. Hyper-text markup language (html).
- Next: Html. Full: Hyper-text markup language (html).
- Prefer capitals? Extensible markup language (XML). Next: XML. Full: extensible markup language (XML).
- Prefer small-caps? Cascading style sheet (CSS). Next: CSS. Full: cascading style sheet (CSS).
- Resetting all acronyms.
- Here are the acronyms again:
- Hyper-text markup language (HTML), extensible markup language (XML) and cascading style sheet (CSS).
- Next use: HTML, XML and CSS.
- Full form: Hyper-text markup language (HTML), extensible markup language (XML) and cascading style sheet (CSS).



- Provide your own link text: style sheet.

The verbatim \LaTeX code of Sec. E3 is in List. E.3.

Listing E.3: Sample \LaTeX code for abbreviations usage

```

1 Again please see List.~\ref{lst:abbrv}. Here is an example of first use:
   \acr{ac}. Next use: \acr{ac}. Full: \gls{ac}. Here's an acronym
   referenced using \verb| \acr |: \acr{html}. And here it is again: \
   acr{html}. If you are used to the \texttt{glossaries} package, note
   the difference in using \verb| \gls |: \gls{html}. And again (no
   difference): \gls{html}. Here are some more entries:
2
3 \begin{itemize}
4
5   \item \acr{xml} and \acr{css}.
6
7   \item Next use: \acr{xml} and \acr{css}.
8
9   \item Full form: \gls{xml} and \gls{css}.
10
11  \item Reset again. \glsresetall{abbreviation}
12
13  \item Start with a capital. \Acr{html}.
14
15  \item Next: \Acr{html}. Full: \Gls{html}.
16
17  \item Prefer capitals? \renewcommand{\acronymfont}[1]{\
   MakeTextUppercase{#1}} \Acr{xml}. Next: \acr{xml}. Full: \gls{xml}
   }.
18
19  \item Prefer small-caps? \renewcommand{\acronymfont}[1]{\textsc{#1}}
   \Acr{css}. Next: \acr{css}. Full: \gls{css}.
20
21  \item Resetting all acronyms.\glsresetall{abbreviation}
22
23  \item Here are the acronyms again:
24
25  \item \Acr{html}, \acr{xml} and \acr{css}.
26
27  \item Next use: \Acr{html}, \acr{xml} and \acr{css}.
28
29  \item Full form: \Gls{html}, \gls{xml} and \gls{css}.
30
31  \item Provide your own link text: \glslink{[textbf]css}{style}
32
33 \end{itemize}

```



E4 Glossary

This section shows examples of the use of `\gls{ }` commands in conjunction with the items that are in the `glossary.tex` and `notation.tex` files. Note that entries in `notation.tex` are prefixed with “not:” label (see List. E.4).

Please make sure that the entries in `notation.tex` are those that are referenced in the \LaTeX document files used by this Thesis. Please comment out unused notations and be careful with the commas and brackets in `notation.tex`.

- Matrices are usually denoted by a bold capital letter, such as \mathbf{A} . The matrix’s (i, j) th element is usually denoted a_{ij} . Matrix \mathbf{I} is the identity matrix.
- A set, denoted as \mathcal{S} , is a collection of objects.
- The universal set, denoted as \mathcal{U} , is the set of everything.
- The empty set, denoted as \emptyset , contains no elements.
- Functional Analysis is seen as the study of complete normed vector spaces, i.e., Banach spaces.
- The cardinality of a set, denoted as $|\mathcal{S}|$, is the number of elements in the set.

The verbatim \LaTeX code for the part of Sec. E4 is in List. E.4.

Listing E.4: Sample \LaTeX code for glossary and notations usage

```

1 \begin{itemize}
2
3   \item \Gls{matrix} are usually denoted by a bold capital letter,
      such as  $\mathbf{A}$ . The  $\text{\Gls{matrix}}$ 's  $(i,j)$ th element is
      usually denoted  $a_{ij}$ .  $\text{\Gls{matrix}}$   $\mathbf{I}$  is the
      identity  $\text{\Gls{matrix}}$ .
4
5   \item A set, denoted as  $\text{\Gls{not:set}}$ , is a collection of objects.
6
7   \item The universal set, denoted as  $\text{\Gls{not:universalSet}}$ , is the
      set of everything.
8
9   \item The empty set, denoted as  $\text{\Gls{not:emptySet}}$ , contains no
      elements.
10
11   \item  $\text{\Gls{Functional Analysis}}$  is seen as the study of complete
      normed vector spaces, i.e., Banach spaces.
12
13   \item The cardinality of a set, denoted as  $\text{\Gls{not:cardinality}}$ , is
      the number of elements in the set.
14
15 \end{itemize}

```



E5 Figure

This section shows several ways of placing figures. PDFL^AT_EX compatible files are PDF, PNG, and JPG. Please see the `figure` subdirectory.

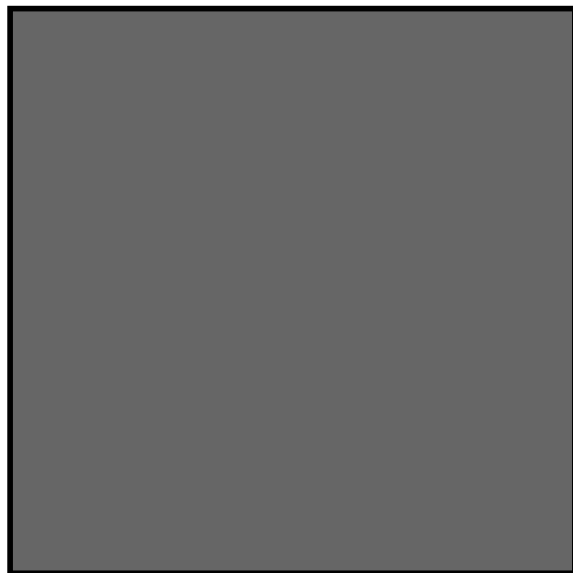


Fig. E.1 A quadrilateral image example.



Fig. E.1 is a gray box enclosed by a dark border. List. E.5 shows the corresponding \LaTeX code.

Listing E.5: Sample \LaTeX code for a single figure

```
1 \begin{figure}[!htbp]
2   \centering
3   \includegraphics[width=0.5\textwidth]{example}
4   \caption{A quadrilateral image example.}
5   \label{fig:example}
6 \end{figure}
7 \cleardoublepage
8
9 Fig.~\ref{fig:example} is a gray box enclosed by a dark border. List.~\
  ref{lst:onefig} shows the corresponding  $\text{\LaTeX}$  \ code.
10 \end{figure}
```



(a) A sub-figure in the top row.



(b) A sub-figure in the middle row.



(c) A sub-figure in the bottom row.

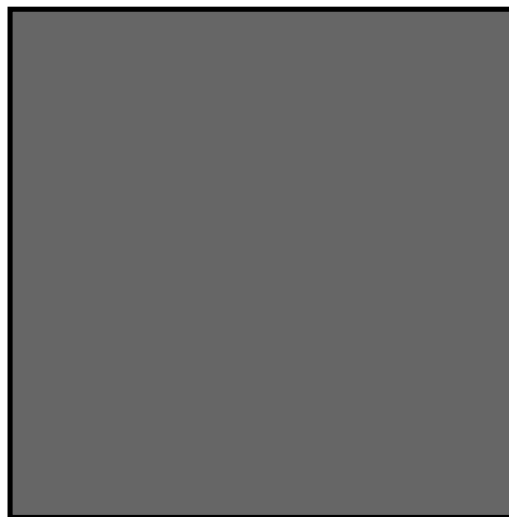
Fig. E.2 Figures on top of each other. See List. E.6 for the corresponding \LaTeX code.

Listing E.6: Sample L^AT_EX code for three figures on top of each other

```
1 \begin{figure}[!htbp]
2 \centering
3 \subbottom[A sub-figure in the top row.]{
4 \includegraphics[width=0.35\textwidth]{example_gray_box}
5 \label{fig:top}
6 }
7 \vfill
8 \subbottom[A sub-figure in the middle row.]{
9 \includegraphics[width=0.35\textwidth]{example_gray_box}
10 \label{fig:mid}
11 }
12 \vfill
13 \subbottom[A sub-figure in the bottom row.]{
14 \includegraphics[width=0.35\textwidth]{example_gray_box}
15 \label{fig:botm}
16 }
17 \caption{Figures on top of each other}
18 \label{fig:tmb}
19 \end{figure}
```



(a) A sub-figure in the upper-left corner.



(b) A sub-figure in the upper-right corner.



(c) A sub-figure in the lower-left corner.



(d) A sub-figure in the lower-right corner

Fig. E.3 Four figures in each corner. See List. E.7 for the corresponding \LaTeX code.

Listing E.7: Sample \LaTeX code for the four figures

```

1 \begin{figure}[!htbp]
2 \centering
3 \subbottom[A sub-figure in the upper-left corner.]{
4 \includegraphics[width=0.45\textwidth]{example_gray_box}
5 \label{fig:upprleft}
6 }
7 \hfill
8 \subbottom[A sub-figure in the upper-right corner.]{
9 \includegraphics[width=0.45\textwidth]{example_gray_box}
10 \label{fig:uppright}
11 }
12 \vfill
13 \subbottom[A sub-figure in the lower-left corner.]{
14 \includegraphics[width=0.45\textwidth]{example_gray_box}
15 \label{fig:lowerleft}
16 }
17 \hfill
18 \subbottom[A sub-figure in the lower-right corner]{
19 \includegraphics[width=0.45\textwidth]{example_gray_box}
20 \label{fig:lowright}
21 }
22 \caption{Four figures in each corner. See List.\ref{lst:fourfigs} for
23 the corresponding \LaTeX \ code.}
24 \label{fig:fourfig}
25 \end{figure}

```



E6 Table

This section shows an example of placing a table (a long one). Table E.1 are the triples.

TABLE E.1 FEASIBLE TRIPLES FOR HIGHLY VARIABLE GRID

Time (s)	Triple chosen	Other feasible triples
0	(1, 11, 13725)	(1, 12, 10980), (1, 13, 8235), (2, 2, 0), (3, 1, 0)
2745	(1, 12, 10980)	(1, 13, 8235), (2, 2, 0), (2, 3, 0), (3, 1, 0)
5490	(1, 12, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
8235	(1, 12, 16470)	(1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0)
10980	(1, 12, 16470)	(1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0)
13725	(1, 12, 16470)	(1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0)
16470	(1, 13, 16470)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
19215	(1, 12, 16470)	(1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0)
21960	(1, 12, 16470)	(1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0)
24705	(1, 12, 16470)	(1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0)
27450	(1, 12, 16470)	(1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0)
30195	(2, 2, 2745)	(2, 3, 0), (3, 1, 0)
32940	(1, 13, 16470)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
35685	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
38430	(1, 13, 10980)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
41175	(1, 12, 13725)	(1, 13, 10980), (2, 2, 2745), (2, 3, 0), (3, 1, 0)
43920	(1, 13, 10980)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
46665	(2, 2, 2745)	(2, 3, 0), (3, 1, 0)
49410	(2, 2, 2745)	(2, 3, 0), (3, 1, 0)
52155	(1, 12, 16470)	(1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0)
54900	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
57645	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
60390	(1, 12, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
63135	(1, 13, 16470)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
65880	(1, 13, 16470)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
68625	(2, 2, 2745)	(2, 3, 0), (3, 1, 0)
71370	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
74115	(1, 12, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
76860	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
79605	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
82350	(1, 12, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
85095	(1, 12, 13725)	(1, 13, 10980), (2, 2, 2745), (2, 3, 0), (3, 1, 0)
87840	(1, 13, 16470)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
90585	(1, 13, 16470)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
93330	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
96075	(1, 13, 16470)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
98820	(1, 13, 16470)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
101565	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
104310	(1, 13, 16470)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
107055	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
109800	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
112545	(1, 12, 16470)	(1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0)
115290	(1, 13, 16470)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
118035	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
120780	(1, 13, 16470)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
123525	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)

Continued on next page



Continued from previous page

Time (s)	Triple chosen	Other feasible triples
126270	(1, 12, 16470)	(1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0)
129015	(2, 2, 2745)	(2, 3, 0), (3, 1, 0)
131760	(2, 2, 2745)	(2, 3, 0), (3, 1, 0)
134505	(1, 13, 16470)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
137250	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
139995	(2, 2, 2745)	(2, 3, 0), (3, 1, 0)
142740	(2, 2, 2745)	(2, 3, 0), (3, 1, 0)
145485	(1, 12, 16470)	(1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0)
148230	(2, 2, 2745)	(2, 3, 0), (3, 1, 0)
150975	(1, 13, 16470)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
153720	(1, 12, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
156465	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
159210	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
161955	(1, 13, 16470)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
164700	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)



List. E.8 shows the corresponding \LaTeX code.

Listing E.8: Sample \LaTeX code for making typical table environment

```

1 \begin{center}
2 {\scriptsize
3 \begin{tabularx}{\textwidth}{p{0.1\textwidth}|p{0.2\textwidth}|p{0.5\textwidth}}
4 \caption{Feasible triples for highly variable grid} \label{tab:triple_
   grid} \\
5 \hline
6 \hline
7 \textbf{Time (s)} &
8 \textbf{Triple chosen} &
9 \textbf{Other feasible triples} \\
10 \hline
11 \endfirsthead
12 \multicolumn{3}{c}{\textit{Continued from previous page}} \\
13 \hline
14 \hline
15 \textbf{Time (s)} &
16 \textbf{Triple chosen} &
17 \textbf{Other feasible triples} \\
18 \hline
19 \endhead
20 \hline
21 \hline
22 \multicolumn{3}{r}{\textit{Continued on next page}} \\
23 \endfoot
24 \hline
25 \endlastfoot
26 \hline
27
28 0 & (1, 11, 13725) & (1, 12, 10980), (1, 13, 8235), (2, 2, 0), (3, 1, 0) \\
   & \\
29 2745 & (1, 12, 10980) & (1, 13, 8235), (2, 2, 0), (2, 3, 0), (3, 1, 0) \\
   & \\
30 5490 & (1, 12, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
31 8235 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, \\
   & 0) \\
32 10980 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, \\
   & 0) \\
33 13725 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, \\
   & 0) \\
34 16470 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
35 19215 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, \\
   & 0) \\
36 21960 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, \\
   & 0) \\
37 24705 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, \\
   & 0) \\
38 27450 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, \\
   & 0) \\
39 30195 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
40 32940 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
41 35685 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
42 38430 & (1, 13, 10980) & (2, 2, 2745), (2, 3, 0), (3, 1, 0)

```



```

43 41175 & (1, 12, 13725) & (1, 13, 10980), (2, 2, 2745), (2, 3, 0), (3, 1,
    0) \\
44 43920 & (1, 13, 10980) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
45 46665 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
46 49410 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
47 52155 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1,
    0) \\
48 54900 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
49 57645 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
50 60390 & (1, 12, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
51 63135 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
52 65880 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
53 68625 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
54 71370 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
55 74115 & (1, 12, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
56 76860 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
57 79605 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
58 82350 & (1, 12, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
59 85095 & (1, 12, 13725) & (1, 13, 10980), (2, 2, 2745), (2, 3, 0), (3, 1,
    0) \\
60 87840 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
61 90585 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
62 93330 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
63 96075 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
64 98820 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
65 101565 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
66 104310 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
67 107055 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
68 109800 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
69 112545 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3,
    1, 0) \\
70 115290 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
71 118035 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
72 120780 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
73 123525 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
74 126270 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3,
    1, 0) \\
75 129015 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
76 131760 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
77 134505 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
78 137250 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
79 139995 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
80 142740 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
81 145485 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3,
    1, 0) \\
82 148230 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
83 150975 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
84 153720 & (1, 12, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
85 156465 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
86 159210 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
87 161955 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
88 164700 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
89 \end{tabularx}
90 }
91 \end{center}

```



E7 Algorithm or Pseudocode Listing

Table E.2 shows an example pseudocode. Note that if the pseudocode exceeds one page, it can mean that its implementation is not modular. List. E.9 shows the corresponding \LaTeX code.

TABLE E.2 CALCULATION OF $y = x^n$

Input(s):	
n	: n th power; $n \in \mathbb{Z}^+$
x	: base value; $x \in \mathbb{R}^+$
Output(s):	
y	: result; $y \in \mathbb{R}^+$

Require: $n \geq 0 \vee x \neq 0$

Ensure: $y = x^n$

```

1:  $y \leftarrow 1$ 
2: if  $n < 0$  then
3:    $X \leftarrow 1/x$ 
4:    $N \leftarrow -n$ 
5: else
6:    $X \leftarrow x$ 
7:    $N \leftarrow n$ 
8: end if
9: while  $N \neq 0$  do
10:  if  $N$  is even then
11:     $X \leftarrow X \times X$ 
12:     $N \leftarrow N/2$ 
13:  else  $\{N \text{ is odd}\}$ 
14:     $y \leftarrow y \times X$ 
15:     $N \leftarrow N - 1$ 
16:  end if
17: end while

```

Listing E.9: Sample L^AT_EX code for algorithm or pseudocode listing usage

```

1 \begin{table}[!htbp]
2   \caption{Calculation of  $y = x^n$ }
3   \label{tab:calcxn}
4   {\footnotesize
5     \begin{tabular}{lll}
6       \hline
7       \hline
8       {\bfseries Input(s):} & & \\
9       $n$ & : & $n$th power; $n$ \in \mathbb{Z}^{+}$ \\
10      $x$ & : & base value; $x$ \in \mathbb{R}^{+}$ \\
11      \hline
12      {\bfseries Output(s):} & & \\
13      $y$ & : & result; $y$ \in \mathbb{R}^{+}$ \\
14      \hline
15      \hline
16      \\
17    \end{tabular}
18  }
19  \begin{algorithmic}[1]
20    {\footnotesize
21      \REQUIRE $n \geq 0$ \vee $x \neq 0$
22      \ENSURE $y = x^n$
23      \STATE $y \leftarrow 1$
24      \IF{$n < 0$}
25        \STATE $X \leftarrow 1 / x$
26        \STATE $N \leftarrow -n$
27      \ELSE
28        \STATE $X \leftarrow x$
29        \STATE $N \leftarrow n$
30      \ENDIF
31      \WHILE{$N \neq 0$}
32        \IF{$N$ is even}
33          \STATE $X \leftarrow X \times X$
34          \STATE $N \leftarrow N / 2$
35        \ELSE[$N$ is odd]
36          \STATE $y \leftarrow y \times X$
37          \STATE $N \leftarrow N - 1$
38        \ENDIF
39      \ENDWHILE
40    }
41  \end{algorithmic}
42 \end{table}

```



E8 Program/Code Listing

List. E.10 is a program listing of a C code for computing Fibonacci numbers by calling the actual code. Please see the `code` subdirectory.

Listing E.10: Computing Fibonacci numbers in C (./code/fibo.c)

```

1  /* fibo.c -- It prints out the first N Fibonacci
2  *              numbers.
3  */
4
5  #include <stdio.h>
6
7  int main(void) {
8      int n;          /* Number of fibonacci numbers we will print */
9      int i;          /* Index of fibonacci number to be printed next */
10     int current;     /* Value of the (i)th fibonacci number */
11     int next;        /* Value of the (i+1)th fibonacci number */
12     int twoaway;     /* Value of the (i+2)th fibonacci number */
13
14     printf("How many Fibonacci numbers do you want to compute? ");
15     scanf("%d", &n);
16     if (n<=0)
17         printf("The number should be positive.\n");
18     else {
19         printf("\n\n\tI\t\tFibonacci(I)\t\n\t===== \n");
20         next = current = 1;
21         for (i=1; i<=n; i++) {
22             printf("\t%d\t\t\t%d\n", i, current);
23             twoaway = current+next;
24             current = next;
25             next = twoaway;
26         }
27     }
28 }
29
30 /* The output from a run of this program was:
31
32 How many Fibonacci numbers do you want to compute? 9
33
34     I      Fibonacci(I)
35     =====
36     1      1
37     2      1
38     3      2
39     4      3
40     5      5
41     6      8
42     7     13
43     8     21
44     9     34
45
46 */

```




List. E.11 shows the corresponding \LaTeX code.

Listing E.11: Sample \LaTeX code for program listing

```
1 List.~\ref{lst:fib_c} is a program listing of a C code for computing  
   Fibonacci numbers by calling the actual code. Please see the \verb|  
   code | subdirectory.
```



E9 Referencing

Referencing chapters: This appendix is in Appendix E, which is about examples in using various \LaTeX commands.

Referencing sections: This section is Sec. E9, which shows how to refer to the locations of various labels that have been placed in the \LaTeX files. List. E.12 shows the corresponding \LaTeX code.

Listing E.12: Sample \LaTeX code for referencing sections

```
1 Referencing sections: This section is Sec.~\ref{sec:ref}, which shows
   how to refer to the locations of various labels that have been
   placed in the \LaTeX \ files. List.~\ref{lst:refsec} shows the
   corresponding \LaTeX \ code.
```

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem. Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor. Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris. Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit amet ipsum. Nunc quis urna dictum turpis accumsan semper.



E9.1 A subsection

Referencing subsections: This section is Sec. E9.1, which shows how to refer to a subsection. List. E.13 shows the corresponding \LaTeX code.

Listing E.13: Sample \LaTeX code for referencing subsections

```
1 Referencing subsections: This section is Sec.~\ref{sec:subsec}, which
  shows how to refer to a subsection. List.~\ref{lst:refsub} shows the
  corresponding \LaTeX \ code.
```

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E9.1.1 A sub-subsection

Referencing sub-subsections: This section is Sec. E9.1.1, which shows how to refer to a sub-subsection. List. E.14 shows the corresponding \LaTeX code.

Listing E.14: Sample \LaTeX code for referencing sub-subsections

```
1 Referencing sub-subsections: This section is Sec.~\ref{sec:subsubsec},
   which shows how to refer to a sub-subsection. List.~\ref{lst:
   refsubsub} shows the corresponding \LaTeX \ code.
```

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem. Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor. Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris. Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit amet ipsum. Nunc quis urna dictum turpis accumsan semper.



E10 Citing

Citing bibliography content is done using BibTeX. It requires the creation of a BibTeX file (.bib extension name), and then added in the argument of `\bibliography{ }`. For each .bib file, separate them by a comma in the argument of `\bibliography{ }` without the extension name. Building your BibTeX file (references.bib) can be done easily with a tool called JabRef (www.jabref.org).

The following subsections are examples of citations.

E10.1 Books

- ['Chicago', 1982]
- [Aristotle, 1877]
- [Aristotle, 1907]
- [Aristotle, 1968]
- [Aristotle, 1929]
- [ABCM, 1959]
- [Augustine, 1995]
- [Averroes, 1982]
- [Butcher, 1981]
- [Chapman, 1975]
- [Cicero, 1995]
- [Coleridge, 1983]
- [Cotton et al., 1999]
- [van Gennep, 1909a]
- [van Gennep, 1909b]
- [van Gennep, 1960]
- [Gerhardt, 2000]
- [Gonzalez, 2001]



- [Goossens et al., 1994]
- [Hammond, 1997]
- [HersHKovitz, 1962]
- [Hoel, 1971a]
- [Homer, 2004]
- [Knuth, 1981a]
- [Knuth, 1981b]
- [Knuth, 1973a]
- [Kullback, 1997a]
- [Kullback, 1997b]
- [Kullback, 1959]
- [Malinowski, 1972]
- [Maron, 2000]
- [Massa, 2004]
- [McColvin, 2004]
- [Nietzsche, 1988b]
- [Nietzsche, 1988a]
- [Oetiker et al., 2014]
- [Piccato, 2001]
- [Smart, 1976]
- [Vázquez de Parga et al., 1993]
- [Wilde, 1899]
- [Wood, 1961]
- [Worman, 2002]
- [Wright, 1978a]
- [Lipcoll et al., 1977]

**E10.2 Booklets**

- [Knvth, 1988]

E10.3 Proceedings

- [Oz and Yannakakis, 1983]

E10.4 In books

- [von Brandt and Hoffmann, 1987]
- [BSI, 1973a]
- [Eckstein and Zuckermann, 1960]
- [Feigl, 1958]
- [Gordon, 1975]
- [Hanson, 1967]
- [Hoel, 1971b]
- [Hyman, 1981]
- [Kant, 1968a]
- [Kant, 1968b]
- [Knuth, 1973b]
- [Knuth, 1973c]
- [Lincoll, 1977a]
- [Lincoll, 2004]
- [Lincoll, 1977b]
- [McNeill, 1963]
- [Milton, 1924]
- [Nietzsche, 1988c]



- [Ogilvy, 1965]
- [Pines, 1979]
- [Ramsbottom, 1931]
- [Ranganthan, 1951]
- [Thomson, 1971]
- [Westfahl, 2004]
- [Wright, 1963]
- [Wright, 1978b]

E10.5 In proceedings

- [Chave, 1964]
- [Chomsky, 1973]
- [Moraux, 1979]
- [Oaho et al., 1983a]
- [Oaho et al., 2004]
- [Oaho et al., 1983b]
- [Salam, 1968]

E10.6 Journals

- [Aamport, 2004]
- [Aamport, 1986a]
- [Aamport, 1986b]
- [Aksın et al., 2006]
- [Angenendt, 2002]
- [Aslin, 1949]



- [Baez and Lauda, 2004a]
- [Bertram and Wentworth, 1996]
- [Bry and Afflerbach, 1968]
- [Doody, 1974]
- [Einstein, 1905]
- [Fletcher and Hopkins, 1907]
- [Gillies, 1933]
- [Glashow, 1961]
- [Godfrey, 1959]
- [Hanlon, 1972]
- [Heller and Lederis, 1958]
- [Herrmann et al., 2006]
- [Hostetler et al., 1998]
- [Howells, 1966a]
- [Howells, 1966b]
- [Howells, 1951]
- [ISO, 2009]
- [Jackson, 1979]
- [Johnson, 1974]
- [Moore, 1998]
- [Moore, 1965]
- [Prufer, 1964]
- [Reese, 1958]
- [Sarfraz and Razzak, 2002]



- [Shore, 1991]
- [Sigfridsson and Ryde, 1998]
- [Weinberg, 1967]
- [Yoon et al., 2006]
- [GAJ, 1986]

E10.7 Theses/dissertations

- [Croft, 1978]
- [Maguire, 1976]
- [Mann, 1968]
- [Masterly, 1988a]
- [Masterly, 1988b]
- [Phony-Baloney, 1988a]
- [Phony-Baloney, 1988b]

E10.8 Technical Reports and Others

- ['Brunswick', 1985]
- [BSI, 1983]
- [BSI, 1978]
- [BSI, 1976]
- [BSI, 1973b]
- [Ellis and Walton, 1971]
- [Terrific, 1988]
- [Terrific, 1988]
- [Winget Ltd., 1967]



- [Ünderwood et al., 2004]
- [Ünderwood et al., 1988]
- [Downes, 1974]
- [Exchequer, 1639]
- [Pym, 1624]
- [Traquair, 1638]

E10.9 Miscellaneous

- [Almendro et al., 1998]
- [Baez and Lauda, 2004b]
- [Chiu and Chow, 1978]
- [Itzhaki, 1996]
- [Kowalik and Isard, 1995]
- [Laufenberg et al., 2006]
- [Loh, 1992]
- [Markey, 2005]
- [Missilany, 1984]
- [Padhye et al., 1999]
- [Sorace et al., 1997]
- [Wassenberg and Sanders, 2010]
- [Missilany, 2004]



E11 Index

For key words or topics that are expected (or the user would like) to appear in the Index, use `\index{key}`, where `key` is an example keyword to appear in the Index. For example, Fredholm integral and Fourier operator of the following paragraph are in the Index.

If we make a very large matrix with complex exponentials in the rows (i.e., cosine real parts and sine imaginary parts), and increase the resolution without bound, we approach the kernel of the Fredholm integral equation of the 2nd kind, namely the Fourier operator that defines the continuous Fourier transform.

List. E.15 is a program listing of the above-mentioned paragraph.

Listing E.15: Sample \LaTeX code for Index usage

```
1 If we make a very large matrix with complex exponentials in the rows (i.
  e., cosine real parts and sine imaginary parts), and increase the
  resolution without bound, we approach the kernel of the \index{
  Fredholm integral} Fredholm integral equation of the 2nd kind,
  namely the \index{Fourier} Fourier operator that defines the
  continuous Fourier transform.
```



E12 Adding Relevant PDF Pages

Examples of such PDF pages are Standards, Datasheets, Specification Sheets, Application Notes, etc. Selected PDF pages can be added (see List. E.16), but note that the options must be tweaked. See the manual of `pdfpages` for other options.

Listing E.16: Sample \LaTeX code for including PDF pages

```
1 \includepdf[pages={8-10},%  
2 offset=3.5mm -10mm,%  
3 scale=0.73,%  
4 frame,%  
5 pagecommand={},]  
6 {./reference/Xilinx2015-UltraScale-Architecture-Overview.pdf}
```



Virtex UltraScale FPGA Feature Summary

Table 6: Virtex UltraScale FPGA Feature Summary

	VU065	VU080	VU095	VU125	VU160	VU190	VU440
Logic Cells	626,640	780,000	940,800	1,253,280	1,621,200	1,879,920	4,432,680
CLB Flip-Flops	716,160	891,424	1,075,200	1,432,320	1,852,800	2,148,480	5,065,920
CLB LUTs	358,080	445,712	537,600	716,160	926,400	1,074,240	2,532,960
Maximum Distributed RAM (Mb)	4.8	3.9	4.8	9.7	12.7	14.5	28.7
Block RAM/FIFO w/ECC (36Kb each)	1,260	1,421	1,728	2,520	3,276	3,780	2,520
Total Block RAM (Mb)	44.3	50.0	60.8	88.6	115.2	132.9	88.6
CMT (1 MMCM, 2 PLLs)	10	16	16	20	30	30	30
I/O DLLs	40	64	64	80	120	120	120
Fractional PLLs	5	8	8	10	15	15	0
Maximum HP I/Os ⁽¹⁾	468	780	780	780	650	650	1,404
Maximum HR I/Os ⁽²⁾	52	52	52	104	52	52	52
DSP Slices	600	672	768	1,200	1,560	1,800	2,880
System Monitor	1	1	1	2	3	3	3
PCIe Gen3 x8	2	4	4	4	5	6	6
150G Interlaken	3	6	6	6	8	9	0
100G Ethernet	3	4	4	6	9	9	3
GTH 16.3Gb/s Transceivers	20	32	32	40	52	60	48
GTY 30.5Gb/s Transceivers	20	32	32	40	52	60	0

Notes:

1. HP = High-performance I/O with support for I/O voltage from 1.0V to 1.8V.
2. HR = High-range I/O with support for I/O voltage from 1.2V to 3.3V.



Virtex UltraScale Device-Package Combinations and Maximum I/Os

Table 7: Virtex UltraScale Device-Package Combinations and Maximum I/Os

Package ⁽¹⁾⁽²⁾⁽³⁾	Package Dimensions (mm)	VU065	VU080	VU095	VU125	VU160	VU190	VU440
		HR, HP GTH, GTY	HR, HP GTH, GTY	HR, HP GTH, GTY	HR, HP GTH, GTY	HR, HP GTH, GTY	HR, HP GTH, GTY	HR, HP GTH, GTY
FFVC1517	40x40	52, 468 20, 20	52, 468 20, 20	52, 468 20, 20				
FFVD1517	40x40		52, 286 32, 32	52, 286 32, 32				
FLVD1517	40x40				52, 286 40, 32			
FFVB1760	42.5x42.5		52, 650 32, 16	52, 650 32, 16				
FLVB1760	42.5x42.5				52, 650 36, 16			
FFVA2104	47.5x47.5		52, 780 28, 24	52, 780 28, 24				
FLVA2104	47.5x47.5				52, 780 28, 24			
FFVB2104	47.5x47.5		52, 650 32, 32	52, 650 32, 32				
FLVB2104	47.5x47.5				52, 650 40, 36			
FLGB2104	47.5x47.5					52, 650 40, 36	52, 650 40, 36	
FFVC2104	47.5x47.5			52, 364 32, 32				
FLVC2104	47.5x47.5				52, 364 40, 40			
FLGC2104	47.5x47.5					52, 364 52, 52	52, 364 52, 52	
FLGB2377	50x50							52, 1248 36, 0
FLGA2577	52.5x52.5						0, 448 60, 60	
FLGA2892	55x55							52, 1404 48, 0

Notes:

1. Go to [Ordering Information](#) for package designation details.
2. All packages have 1.0mm ball pitch.
3. Packages with the same last letter and number sequence, e.g., A2104, are footprint compatible with all other UltraScale architecture-based devices with the same sequence. The footprint compatible devices within this family are outlined. See the [UltraScale Architecture Product Selection Guide](#) for details on inter-family migration.



Virtex UltraScale+ FPGA Feature Summary

Table 8: Virtex UltraScale+ FPGA Feature Summary

	VU3P	VU5P	VU7P	VU9P	VU11P	VU13P
Logic Cells	689,640	1,051,010	1,379,280	2,068,920	2,147,040	2,862,720
CLB Flip-Flops	788,160	1,201,154	1,576,320	2,364,480	2,453,760	3,271,680
CLB LUTs	394,080	600,577	788,160	1,182,240	1,226,880	1,635,840
Max. Distributed RAM (Mb)	12.0	18.3	24.1	36.1	34.8	46.4
Block RAM/FIFO w/ECC (36Kb each)	720	1,024	1,440	2,160	2,016	2,688
Block RAM (Mb)	25.3	36.0	50.6	75.9	70.9	94.5
UltraRAM Blocks	320	470	640	960	1,152	1,536
UltraRAM (Mb)	90.0	132.2	180.0	270.0	324.0	432.0
CMTs (1 MMCM and 2 PLLs)	10	20	20	30	12	16
Max. HP I/O ⁽¹⁾	520	832	832	832	624	832
DSP Slices	2,280	3,474	4,560	6,840	8,928	11,904
System Monitor	1	2	2	3	3	4
GTY Transceivers 32.75Gb/s	40	80	80	120	96	128
PCIe Gen3 x16 and Gen4 x8	2	4	4	6	3	4
150G Interlaken	3	4	6	9	9	12
100G Ethernet w/RS-FEC	3	4	6	9	6	8

Notes:

1. HP = High-performance I/O with support for I/O voltage from 1.0V to 1.8V.

Virtex UltraScale+ Device-Package Combinations and Maximum I/Os

Table 9: Virtex UltraScale+ Device-Package Combinations and Maximum I/Os

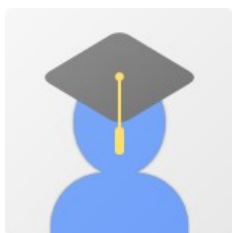
Package (1)(2)(3)	Package Dimensions (mm)	VU3P	VU5P	VU7P	VU9P	VU11P	VU13P
		HP, GTY	HP, GTY	HP, GTY	HP, GTY	HP, GTY	HP, GTY
FFVC1517	40x40	520, 40					
FLVF1924	45x45					624, 64	
FLVA2104	47.5x47.5		832, 52	832, 52	832, 52		
FHVA2104	52.5x52.5 ⁽⁴⁾						832, 52
FLVB2104	47.5x47.5		702, 76	702, 76	702, 76	624, 76	
FHVB2104	52.5x52.5 ⁽⁴⁾						702, 76
FLVC2104	47.5x47.5		416, 80	416, 80	416, 104	416, 96	
FHVC2104	52.5x52.5 ⁽⁴⁾						416, 104
FLVA2577	52.5x52.5				448, 120	448, 96	448, 128

Notes:

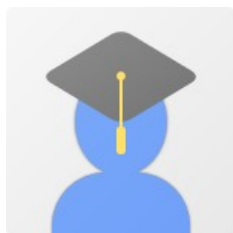
- Go to [Ordering Information](#) for package designation details.
- All packages have 1.0mm ball pitch.
- Packages with the same last letter and number sequence, e.g., A2104, are footprint compatible with all other UltraScale devices with the same sequence. The footprint compatible devices within this family are outlined.
- These 52.5x52.5mm overhang packages have the same PCB ball footprint as the corresponding 47.5x47.5mm packages (i.e., the same last letter and number sequence) and are footprint compatible.



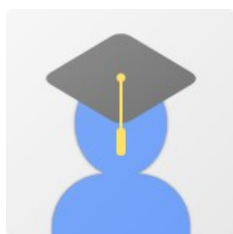
Appendix F VITA



Juan Z. dela Cruz received the B.Sc., M.Sc., and Ph.D. degrees in chemistry all from the Pamantasan ng Pilipinas, San Juan, Metro Manila, Philippines, in 2013, 2015 and 2018 respectively. He is currently taking up his B.Sc. Electronics and Communications Engineering studies. He has developed several high-speed packet-switched network systems and node modules. His research interests include high-speed packet-switched networks, high speed radio interface design, discrete simulation and statistical models for packet switches.



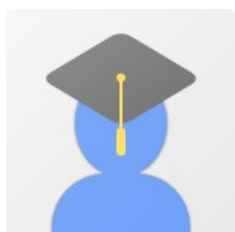
Nat Y. Franco received the B.Sc., M.Sc., and Ph.D. degrees in chemistry all from the Pamantasan ng Pilipinas, San Juan, Metro Manila, Philippines, in 2013, 2015 and 2018 respectively. He is currently taking up his B.Sc. Electronics and Communications Engineering studies. He has developed several high-speed packet-switched network systems and node modules. His research interests include high-speed packet-switched networks, high speed radio interface design, discrete simulation and statistical models for packet switches.



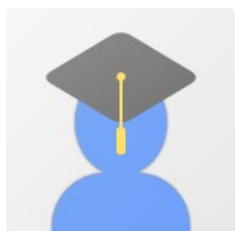
Sebastian X. Garcia received the B.Sc., M.Sc., and Ph.D. degrees in chemistry all from the Pamantasan ng Pilipinas, San Juan, Metro Manila, Philippines, in 2013, 2015 and 2018 respectively. He is currently taking up his B.Sc. Electronics



and Communications Engineering studies. He has developed several high-speed packet-switched network systems and node modules. His research interests include high-speed packet-switched networks, high speed radio interface design, discrete simulation and statistical models for packet switches.



Isabella W. Martinez received the B.Sc., M.Sc., and Ph.D. degrees in chemistry all from the Pamantasan ng Pilipinas, San Juan, Metro Manila, Philippines, in 2013, 2015 and 2018 respectively. He is currently taking up his B.Sc. Electronics and Communications Engineering studies. He has developed several high-speed packet-switched network systems and node modules. His research interests include high-speed packet-switched networks, high speed radio interface design, discrete simulation and statistical models for packet switches.



Max V. Rianzares received the B.Sc., M.Sc., and Ph.D. degrees in chemistry all from the Pamantasan ng Pilipinas, San Juan, Metro Manila, Philippines, in 2013, 2015 and 2018 respectively. He is currently taking up his B.Sc. Electronics and Communications Engineering studies. He has developed several high-speed packet-switched network systems and node modules. His research interests include high-speed packet-switched networks, high speed radio interface design, discrete simulation and statistical models for packet switches.