



A Microcontroller-based System Used to Measure Different Weather Parameters such as  
Temperature, Humidity and Amount of Rainfall

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

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In Partial Fulfillment of the  
Requirements for the Degree of  
Bachelor of Science in Computer Engineering

---

by  
  
CHEONG, Junlae  
NIHALANI, Rohit P.  
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PO, Ryback Tyrone G.

May, 2016



De La Salle University

## ORAL DEFENSE RECOMMENDATION SHEET

This thesis, entitled **A Microcontroller-based System Used to Measure Different Weather Parameters such as Temperature, Humidity and Amount of Rainfall**, prepared and submitted by thesis group, ESG-04, composed of:

CHEONG, Junlae  
NIHALANI, Rohit P.  
PAULINO, Noel B.  
PO, Ryback Tyrone G.

in partial fulfillment of the requirements for the degree of **Bachelor of Science in Computer Engineering (BS-CPE)** has been examined and is recommended for acceptance and approval for **ORAL DEFENSE**.

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May 28, 2016



De La Salle University

## THESIS APPROVAL SHEET

This thesis entitled **A Microcontroller-based System Used to Measure Different Weather Parameters such as Temperature, Humidity and Amount of Rainfall**, prepared and submitted by:

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NIHALANI, Rohit P.  
PAULINO, Noel B.  
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with group number ESG-04 in partial fulfillment of the requirements for the degree of **Bachelor of Science in Computer Engineering (BS-CPE)** has been examined and is recommended for acceptance and approval.

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Date: May 28, 2016



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2016

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## ACKNOWLEDGMENT

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Write this prior to hard binding if you have submitted all requirements and are told by your adviser that you have passed.



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## ABSTRACT

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Keep your abstract short by giving the gist/nutshell of your thesis.

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*Index Terms*—microcontroller, characterization, InP, InGaAs.



70

## TABLE OF CONTENTS

71

Oral Defense Recommendation Sheet	ii
-----------------------------------	----

72

Thesis Approval Sheet	iii
-----------------------	-----

73

Acknowledgment	v
----------------	---

74

Abstract	vi
----------	----

75

Table of Contents	vii
-------------------	-----

76

List of Figures	x
-----------------	---

77

List of Tables	xi
----------------	----

78

Abbreviations	xii
---------------	-----

79

Notation	xiii
----------	------

80

Glossary	xiv
----------	-----

81

Listings	xv
----------	----

82

Chapter 1 INTRODUCTION	1
------------------------	---

83

1.1 Background of the Study . . . . .	2
---------------------------------------	---

84

1.2 Prior Studies . . . . .	4
-----------------------------	---

85

1.3 Problem Statement . . . . .	4
---------------------------------	---

86

1.4 Objectives . . . . .	5
--------------------------	---

87

1.4.1 General Objective(s) . . . . .	5
--------------------------------------	---

88

1.4.2 Specific Objectives . . . . .	5
-------------------------------------	---

89

1.5 Significance of the Study . . . . .	5
---	---

90

1.6 Assumptions, Scope and Delimitations . . . . .	6
--	---

91

1.7 Description and Methodology . . . . .	6
---	---

92

1.8 Overview . . . . .	6
------------------------	---

93

Chapter 2 LITERATURE REVIEW	7
-----------------------------	---

94

2.1 Summary . . . . .	10
-----------------------	----



95	<b>Chapter 3 THEORETICAL CONSIDERATIONS</b>	<b>11</b>
96	3.1 Summary . . . . .	13
97	<b>Chapter 4 DESIGN CONSIDERATIONS</b>	<b>15</b>
98	4.1 Summary . . . . .	17
99	<b>Chapter 5 METHODOLOGY</b>	<b>18</b>
100	5.1 Implementation . . . . .	19
101	5.2 Evaluation . . . . .	21
102	5.3 Summary . . . . .	23
103	<b>Chapter 6 RESULTS AND DISCUSSION</b>	<b>24</b>
104	6.1 Summary . . . . .	26
105	<b>Chapter 7 CONCLUSIONS, RECOMMENDATIONS, AND FUTURE DIREC-</b>	
106	<b>TIVES</b>	<b>27</b>
107	7.1 Concluding Remarks . . . . .	28
108	7.2 Contributions . . . . .	28
109	7.3 Recommendations . . . . .	28
110	7.4 Future Prospects . . . . .	30
111	<b>References</b>	<b>31</b>
112	<b>Appendix A ANSWERS TO QUESTIONS TO THIS THESIS</b>	<b>32</b>
113	A1 How important is the problem to practice? . . . . .	33
114	A2 How will you know if the solution/s that you will achieve would be better	
115	than existing ones? . . . . .	33
116	A2.1 How will you measure the improvement/s? . . . . .	33
117	A2.1.1 What is/are your basis/bases for the improvement/s? . .	34
118	A2.1.2 Why did you choose that/those basis/bases? . . . . .	34
119	A2.1.3 How significant are your measure/s of the improvement/s? .	34
120	A3 What is the difference of the solution/s from existing ones? . . . . .	35
121	A3.1 How is it different from previous and existing ones? . . . . .	35
122	A4 What are the assumptions made (that are behind for your proposed solution	
123	to work)? . . . . .	35
124	A4.1 Will your proposed solution/s be sensitive to these assumptions? .	36
125	A4.2 Can your proposed solution/s be applied to more general cases	
126	when some of the assumptions are eliminated? If so, how? . . . .	36
127	A5 What is the necessity of your approach / proposed solution/s? . . . . .	36
128	A5.1 What will be the limits of applicability of your proposed solution/s? .	37





129	A5.2	What will be the message of the proposed solution to technical people? How about to non-technical managers and business men?	37
130			
131	A6	How will you know if your proposed solution/s is/are correct? . . . . .	37
132	A6.1	Will your results warrant the level of mathematics used (i.e., will the end justify the means)? . . . . .	38
133			
134	A7	Is/are there an/_ alternative way/s to get to the same solution/s? . . . . .	38
135	A7.1	Can you come up with illustrating examples, or even better, counter examples to your proposed solution/s? . . . . .	38
136			
137	A7.2	Is there an approximation that can arrive at the essentially the same proposed solution/s more easily? . . . . .	39
138			
139	A8	If you were the examiner of your proposal, how would you present the proposal in another way? . . . . .	39
140			
141	A8.1	What are the weaknesses of your proposal? . . . . .	39
142	<b>Appendix B</b>	<b>USAGE EXAMPLES</b>	<b>41</b>
143	B1	Equations . . . . .	42
144	B2	Notations . . . . .	44
145	B3	Abbreviation . . . . .	50
146	B4	Glossary . . . . .	52
147	B5	Figure . . . . .	53
148	B6	Table . . . . .	59
149	B7	Algorithm or Pseudocode Listing . . . . .	63
150	B8	Program/Code Listing . . . . .	65
151	B9	Referencing . . . . .	67
152	B9.1	A subsection . . . . .	68
153	B9.1.1	A sub-subsection . . . . .	69
154	B10	Index . . . . .	70
155	B11	Adding Relevant PDF Pages (e.g. Standards, Datasheets, Specification Sheets, Application Notes, etc.) . . . . .	71
156			
157	<b>Appendix C</b>	<b>PUBLICATION LIST AND AWARD</b>	<b>75</b>
158	<b>Appendix D</b>	<b>VITA</b>	<b>77</b>
159	<b>Index</b>		<b>79</b>



160

## LIST OF FIGURES

161

3.1 A quadrilateral image example. . . . . 14

162

B.1 A quadrilateral image example. . . . . 53

163

B.2 Figures on top of each other. See List. B.6 for the corresponding  $\text{\LaTeX}$  code. 55

164

B.3 Four figures in each corner. See List. B.7 for the corresponding  $\text{\LaTeX}$  code. . 57



165

## LIST OF TABLES

166

B.1 Feasible triples for highly variable grid . . . . . 59

167

B.2 Calculation of  $y = x^n$  . . . . . 63



168

## ABBREVIATIONS

169	AC	Alternating Current.....	50
170	CSS	Cascading Style Sheet .....	50
171	HTML	Hyper-text Markup Language .....	50
172	XML	eXtensible Markup Language .....	50



173

## NOTATION

174	$ \mathcal{S} $	the number of elements in the set $\mathcal{S}$ .....	52
175	$\emptyset$	the set with no elements .....	52
176	$h(t)$	impulse response .....	42
177	$\mathcal{S}$	a collection of distinct objects .....	52
178	$\mathcal{U}$	the set containing everything .....	52
179	$x(t)$	input signal represented in the time domain .....	42
180	$y(t)$	output signal represented in the time domain .....	42

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



187

## GLOSSARY

188

matrix a concise and useful way of uniquely representing and working with linear transformations; a rectangular table of elements ..... 52



189

## LISTINGS

190	B.1 Sample $\LaTeX$ code for equations and notations usage . . . . .	43
191	B.2 Sample $\LaTeX$ code for notations usage . . . . .	47
192	B.3 Sample $\LaTeX$ code for abbreviations usage . . . . .	51
193	B.4 Sample $\LaTeX$ code for glossary and notations usage . . . . .	52
194	B.5 Sample $\LaTeX$ code for a single figure . . . . .	54
195	B.6 Sample $\LaTeX$ code for three figures on top of each other . . . . .	56
196	B.7 Sample $\LaTeX$ code for the four figures . . . . .	58
197	B.8 Sample $\LaTeX$ code for making typical table environment . . . . .	61
198	B.9 Sample $\LaTeX$ code for algorithm or pseudocode listing usage . . . . .	64
199	B.10 Computing Fibonacci numbers . . . . .	65
200	B.11 Sample $\LaTeX$ code for program listing . . . . .	66
201	B.12 Sample $\LaTeX$ code for referencing sections . . . . .	67
202	B.13 Sample $\LaTeX$ code for referencing subsections . . . . .	68
203	B.14 Sample $\LaTeX$ code for referencing sub-subsections . . . . .	69
204	B.15 Sample $\LaTeX$ code for Index usage . . . . .	70
205	B.16 Sample $\LaTeX$ code for including PDF pages . . . . .	71



## Chapter 1

### INTRODUCTION

#### Contents

1.1	Background of the Study . . . . .	2
1.2	Prior Studies . . . . .	4
1.3	Problem Statement . . . . .	4
1.4	Objectives . . . . .	5
1.4.1	General Objective(s) . . . . .	5
1.4.2	Specific Objectives . . . . .	5
1.5	Significance of the Study . . . . .	5
1.6	Assumptions, Scope and Delimitations . . . . .	6
1.7	Description and Methodology . . . . .	6
1.8	Overview . . . . .	6





## 221 1.1 Background of the Study

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## 1.2 Prior Studies

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## 1.3 Problem Statement

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## 1.4 Objectives

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### 1.4.1 General Objective(s)

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To ...;

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### 1.4.2 Specific Objectives

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## 1.5 Significance of the Study

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## 1.6 Assumptions, Scope and Delimitations

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## 1.7 Description and Methodology

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## 1.8 Overview

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



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## Chapter 2

324

## LITERATURE REVIEW

325

### Contents

326

327

328

---

2.1	Summary . . . . .	10
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 330 nals, patents, notable conference papers) to prove that no one has done your work yet.

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## 2.1 Summary



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## Chapter 3

378

# THEORETICAL CONSIDERATIONS

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### Contents

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3.1 Summary . . . . .	13
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### 428 3.1 Summary

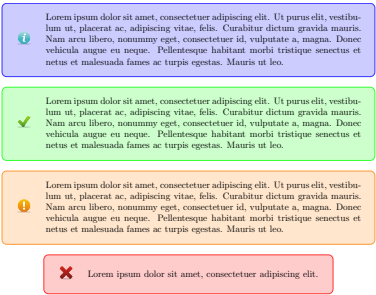


Fig. 3.1 A quadrilateral image example.



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## Chapter 4

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# DESIGN CONSIDERATIONS

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## Contents

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4.1 Summary . . . . .	17
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## 480 4.1 Summary





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## Chapter 5

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## METHODOLOGY

483

### Contents

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485

486

487

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5.1	Implementation . . . . .	19
5.2	Evaluation . . . . .	21
5.3	Summary . . . . .	23

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## 489 5.1 Implementation

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**5.3 Summary**



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## Chapter 6

583

# RESULTS AND DISCUSSION

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### Contents

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6.1 Summary . . . . .	26
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 632 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

## 633 6.1 Summary



## Chapter 7

# CONCLUSIONS, RECOMMENDATIONS, AND FUTURE DIRECTIVES

### Contents

7.1	Concluding Remarks . . . . .	28
7.2	Contributions . . . . .	28
7.3	Recommendations . . . . .	28
7.4	Future Prospects . . . . .	30



644 **7.1 Concluding Remarks**

645 In this Thesis, . . .

646 **7.2 Contributions**

647 The interrelated contributions and supplements that have been developed in this Thesis are  
648 listed as follows.

- 649 • the ;
- 650 • the ;
- 651 • the ;

652 **7.3 Recommendations**

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## 698 7.4 Future Prospects

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

701 1. the ....

702 2. the ....

703 3. the ....



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[Oetiker et al., 2014] Oetiker, T., Partl, H., Hyna, I., and Schlegl, E. (2014). *The Not So Short Introduction to L<sup>A</sup>T<sub>E</sub>X 2<sub>ε</sub> Or L<sup>A</sup>T<sub>E</sub>X 2<sub>ε</sub> in 157 minutes*. n.a.



# Appendix A ANSWERS TO QUESTIONS TO THIS THESIS

## Contents

A1	How important is the problem to practice? . . . . .	33
A2	How will you know if the solution/s that you will achieve would be better than existing ones? . . . . .	33
A2.1	How will you measure the improvement/s? . . . . .	33
A2.1.1	What is/are your basis/bases for the improvement/s? . .	34
A2.1.2	Why did you choose that/those basis/bases? . . . . .	34
A2.1.3	How significant are your measure/s of the improvement/s? .	34
A3	What is the difference of the solution/s from existing ones? . . . . .	35
A3.1	How is it different from previous and existing ones? . . . . .	35
A4	What are the assumptions made (that are behind for your proposed solution to work)? . . . . .	35
A4.1	Will your proposed solution/s be sensitive to these assumptions? .	36
A4.2	Can your proposed solution/s be applied to more general cases when some of the assumptions are eliminated? If so, how? . . . .	36
A5	What is the necessity of your approach / proposed solution/s? . . . . .	36
A5.1	What will be the limits of applicability of your proposed solution/s? .	37
A5.2	What will be the message of the proposed solution to technical people? How about to non-technical managers and business men? .	37
A6	How will you know if your proposed solution/s is/are correct? . . . . .	37
A6.1	Will your results warrant the level of mathematics used (i.e., will the end justify the means)? . . . . .	38
A7	Is/are there an/_ alternative way/s to get to the same solution/s? . . . . .	38
A7.1	Can you come up with illustrating examples, or even better, counter examples to your proposed solution/s? . . . . .	38
A7.2	Is there an approximation that can arrive at the essentially the same proposed solution/s more easily? . . . . .	39
A8	If you were the examiner of your proposal, how would you present the proposal in another way? . . . . .	39
A8.1	What are the weaknesses of your proposal? . . . . .	39



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## **A1 How important is the problem to practice?**

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## **A2 How will you know if the solution/s that you will achieve would be better than existing ones?**

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### **A2.1 How will you measure the improvement/s?**

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776 **A2.1.1 What is/are your basis/bases for the improvement/s?**

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786 **A2.1.2 Why did you choose that/those basis/bases?**

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 788 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec  
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796 **A2.1.3 How significant are your measure/s of the improvement/s?**

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 798 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec  
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### **A3 What is the difference of the solution/s from existing ones?**

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#### **A3.1 How is it different from previous and existing ones?**

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### **A4 What are the assumptions made (that are behind for your proposed solution to work)?**

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838 **A4.1 Will your proposed solution/s be sensitive to these as-**  
 839 **sumptions?**

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849 **A4.2 Can your proposed solution/s be applied to more general**  
 850 **cases when some of the assumptions are eliminated? If**  
 851 **so, how?**

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861 **A5 What is the necessity of your approach / pro-**  
 862 **posed solution/s?**

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871 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

872 **A5.1 What will be the limits of applicability of your proposed so-**  
873 **lution/s?**

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882 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

883 **A5.2 What will be the message of the proposed solution to**  
884 **technical people? How about to non-technical managers**  
885 **and business men?**

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895 **A6 How will you know if your proposed solution/s**  
896 **is/are correct?**

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905 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

906 **A6.1 Will your results warrant the level of mathematics used**  
907 **(i.e., will the end justify the means)?**

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

917 **A7 Is/are there an/\_ alternative way/s to get to the**  
918 **same solution/s?**

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

928 **A7.1 Can you come up with illustrating examples, or even bet-**  
929 **ter, counter examples to your proposed solution/s?**

930 Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem.  
931 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec  
932 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus  
933 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.



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

## 939 **A7.2 Is there an approximation that can arrive at the essen-** 940 **tially the same proposed solution/s more easily?**

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

## 950 **A8 If you were the examiner of your proposal, how** 951 **would you present the proposal in another way?**

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

## 961 **A8.1 What are the weaknesses of your proposal?**

962 Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem.  
 963 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec  
 964 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus  
 965 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.



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



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## **Appendix B**

### **USAGE EXAMPLES**





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

## B1 Equations

The following examples show how to typeset equations in  $\text{\LaTeX}$ . 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  $\text{\LaTeX}$  document files used by this Thesis. Please comment out unused notations and be careful with the commas and brackets in `notation.tex`.**

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

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

Other example equations are as follows.

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

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

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



986

The verbatim  $\text{\LaTeX}$  code of Sec. B1 is in List. B.1.

Listing B.1: Sample  $\text{\LaTeX}$  code for equations and notations usage

```

1 The following examples show how to typeset equations in \LaTeX.
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[ \dfrac{V_{1}}{I_{1}} \right] =
14   \begin{bmatrix}
15     A & B \\
16     C & D
17   \end{bmatrix}
18   \left[ \dfrac{V_{2}}{I_{2}} \right]
19   \label{eq:ABCD}
20 \end{eqnarray}
21
22 \begin{eqnarray}
23   \{1\over 2\} < \left\lfloor \mathrm{mod}\right\left(\left\lfloor y \over 17\right\right\rfloor 2^{\{-17\lfloor x \rfloor - \mathrm{mod}(\lfloor y \rfloor, 17)\},2\right)\right\rfloor,
24 \end{eqnarray}
25
26 \begin{eqnarray}
27   \left| \zeta(x)^3\zeta(x+iy)^4\zeta(x+2iy) \right| =
28   \exp\sum_{n,p}\frac{3+4\cos(ny\log p) +\cos(2ny\log p)}{\{n^p\}^{\geq 1}}
29 \end{eqnarray}

```



## B2 Notations

In order to use the standardized notation, the user is highly suggested to see the ISO 80000-2 standard [ISO, 2009]. The following were taken from `isomath-test.tex`.

### 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>	$A, B, \Gamma, \Delta, \Theta, \Lambda, \Xi, \Pi, \Sigma, \Phi, \Psi, \Omega, \textit{ff}, \textit{fi}, \beta, ^\circ, !, v, w, 0, 1, 9$
<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>	$\mathbf{A, B, \Gamma, \Delta, \Theta, \Lambda, \Xi, \Pi, \Sigma, \Phi, \Psi, \Omega, ff, fi, \beta, ^\circ, !, v, w, 0, 1, 9}$
<code>mathsf</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>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>	$\mathbf{A, B, \Gamma, \Delta, \Theta, \Lambda, \Xi, \Pi, \Sigma, \Phi, \Psi, \Omega, \alpha, \beta, \pi, \nu, \omega, v, w, 0, 1, 9}$
<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>mathsfbfit</code>	$\mathbf{A, B, \Gamma, \Delta, \Theta, \Lambda, \Xi, \Pi, \Sigma, \Phi, \Psi, \Omega, \alpha, \beta, \pi, \nu, \omega, v, w, 0, 1, 9}$

Do the math alphabets match?

$\alpha x \alpha \omega \mathbf{a x \alpha \omega a x \alpha \omega} \quad T C \Theta \Gamma T C \Theta \Gamma T C \Theta \Gamma$

### 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,  $\mathbf{a} + \mathbf{0} = \mathbf{a}$ .

### Matrix symbols

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

<sup>1</sup>However, 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  $\mathbf{E}$ .

1001 **Tensor symbols**

1002 Symbols for tensors are sans-serif bold italic,

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

1003 The permittivity tensor describes the coupling of electric field and displacement:

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



## 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?

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

## 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,  $a + 0 = a$ .

## Matrix symbols

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

## 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:

$$D = \epsilon_0 \epsilon_r E$$

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



1018 The verbatim  $\text{\LaTeX}$  code of Sec. B2 is in List. B.2.

Listing B.2: Sample  $\text{\LaTeX}$  code for notations usage

```

1019 1 % A teststring with Latin and Greek letters::
1020 2 \newcommand{\teststring}{%
1021 3 % capital Latin letters
1022 4 % A,B,C,
1023 5 A,B,
1024 6 % capital Greek letters
1025 7 %\Gamma,\Delta,\Theta,\Lambda,\Xi,\Pi,\Sigma,\Upsilon,\Phi,\Psi,
1026 8 \Gamma,\Delta,\Theta,\Lambda,\Xi,\Pi,\Sigma,\Phi,\Psi,\Omega,
1027 9 % small Greek letters
1028 10 \alpha,\beta,\pi,\nu,\omega,
1029 11 % small Latin letters:
1030 12 % compare \nu, \omega, v, and w
1031 13 v,w,
1032 14 % digits
1033 15 0,1,9
1034 16 }
1035 17
1036 18
1037 19 \subsection*{Math alphabets}
1038 20
1039 21 If there are other symbols in place of Greek letters in a math
1040 22 alphabet, it uses T1 or OT1 font encoding instead of OML.
1041 23
1042 24 \begin{eqnarray*}
1043 25 \mbox{\mathnormal} & & \mbox{\teststring} \\
1044 26 \mbox{\mathit} & & \mbox{\mathit{\teststring}} \\
1045 27 \mbox{\mathrm} & & \mbox{\mathrm{\teststring}} \\
1046 28 \mbox{\mathbf} & & \mbox{\mathbf{\teststring}} \\
1047 29 \mbox{\mathsf} & & \mbox{\mathsf{\teststring}} \\
1048 30 \mbox{\mathtt} & & \mbox{\mathtt{\teststring}} \\
1049 31 \end{eqnarray*}
1050 32 New alphabets bold-italic, sans-serif-italic, and sans-serif-bold-
1051 33 italic.
1052 34 \begin{eqnarray*}
1053 35 \mbox{\mathbfit} & & \mbox{\mathbfit{\teststring}} \\
1054 36 \mbox{\mathsfit} & & \mbox{\mathsfit{\teststring}} \\
1055 37 \mbox{\mathsfbfit} & & \mbox{\mathsfbfit{\teststring}} \\
1056 38 \end{eqnarray*}
1057 39 %
1058 40 Do the math alphabets match?
1059 41 $
1060 42 \mathnormal {a x \alpha \omega}
1061 43 \mathbfit {a x \alpha \omega}
1062 44 \mathsfbfit{a x \alpha \omega}
1063 45 \quad
1064 46 \mathsfbfit{T C \Theta \Gamma}
1065 47 \mathbfit {T C \Theta \Gamma}
1066 48 \mathnormal {T C \Theta \Gamma}
1067 49 $
1068 50
1069 51 \subsection*{Vector symbols}
1070 52

```



```

1073 53 Alphabetic symbols for vectors are boldface italic,
1074 54  $\vec{\lambda} = \vec{e}_1 \cdot \vec{a}$ ,
1075 55 while numeric ones (e.g. the zero vector) are bold upright,
1076 56  $\vec{a} + \vec{0} = \vec{a}$ .
1077 57
1078 58 \subsection*{Matrix symbols}
1079 59
1080 60 Symbols for matrices are boldface italic, too:%
1081 61 \footnote{However, matrix symbols are usually capital letters whereas
1082 62 vectors
1083 62 are small ones. Exceptions are physical quantities like the force
1084 63 vector  $\vec{F}$  or the electrical field  $\vec{E}$ .%
1085 64 }
1086 65  $\Lambda = E \cdot A$ .
1087 66
1088 67
1089 68 \subsection*{Tensor symbols}
1090 69
1091 70 Symbols for tensors are sans-serif bold italic,
1092 71
1093 72 \[
1094 73 \quad \text{\textbf{\textit{tensorsym{\alpha} = tensorsym{e} \cdot tensorsym{a}}}}
1095 74 \quad \text{\textbf{\textit{quad \Longleftarrow \rightarrow quad}}}
1096 75 \quad \text{\textbf{\textit{\alpha_{ijl} = e_{ijk} \cdot a_{kl}}}}
1097 76 \]
1098 77
1099 78
1100 79 The permittivity tensor describes the coupling of electric field and
1101 80 displacement: \[
1102 81 \vec{D} = \epsilon_0 \text{\textbf{\textit{tensorsym{\epsilon}_{\mathrm{r}}}}} \vec{E} \]
1103 82
1104 83
1105 84
1106 85 \newpage
1107 86 \subsection*{Bold math version}
1108 87
1109 88 The ‘‘bold’’ math version is selected with the commands
1110 89 \verb+\boldmath+ or \verb+\mathversion{bold}+
1111 90
1112 91 {\boldmath
1113 92 \begin{eqnarray*}
1114 93 \quad \text{\textbf{\textit{mbox{mathnormal}}} & & \text{\textbf{\textit{teststring}}} \\
1115 94 \quad \text{\textbf{\textit{mbox{mathit}}} & & \text{\textbf{\textit{mathit{teststring}}}}} \\
1116 95 \quad \text{\textbf{\textit{mbox{mathrm}}} & & \text{\textbf{\textit{mathrm{teststring}}}}} \\
1117 96 \quad \text{\textbf{\textit{mbox{mathbf}}} & & \text{\textbf{\textit{mathbf{teststring}}}}} \\
1118 97 \quad \text{\textbf{\textit{mbox{mathsf}}} & & \text{\textbf{\textit{mathsf{teststring}}}}} \\
1119 98 \quad \text{\textbf{\textit{mbox{mathtt}}} & & \text{\textbf{\textit{mathtt{teststring}}}}} \\
1120 99 \end{eqnarray*}
1121 100 \quad \text{New alphabets bold-italic, sans-serif-italic, and sans-serif-bold-}
1122 101 \quad \text{italic.}
1123 102 \begin{eqnarray*}
1124 102 \quad \text{\textbf{\textit{mbox{mathbfit}}} & & \text{\textbf{\textit{mathbfit{teststring}}}}} \\
1125 103 \quad \text{\textbf{\textit{mbox{mathsf}}} & & \text{\textbf{\textit{mathsf{teststring}}}}} \\
1126 104 \quad \text{\textbf{\textit{mbox{mathsfbfit}}} & & \text{\textbf{\textit{mathsfbfit{teststring}}}}} \\
1127 105 \end{eqnarray*}
1128 106 \%
1129 107 Do the math alphabets match?

```



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## B3 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. B.3. **To lessen the  $\LaTeX$  compilation time, it is suggested that you use `\acr{ }` only for the first occurrence of the word to be abbreviated.**

Again please see List. B.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).



- 1206 • Provide your own link text: style sheet.

1207 The verbatim  $\text{\LaTeX}$  code of Sec. B3 is in List. B.3.

### Listing B.3: Sample $\text{\LaTeX}$ 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}

```



## B4 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. B.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  $A$ . The matrix’s  $(i, j)$ th element is usually denoted  $a_{ij}$ . Matrix  $I$  is the identity matrix.
- A set, denoted as  $S$ , 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.
- The cardinality of a set, denoted as  $|S|$ , is the number of elements in the set.

The verbatim  $\LaTeX$  code for the part of Sec. B4 is in List. B.4.

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

```

1 \begin{itemize}
2
3   \item \Glspl{matrix} are usually denoted by a bold capital letter,
      such as  $\mathbf{A}$ . The  $\gls{matrix}$ ’s  $(i, j)$ th element is
      usually denoted  $a_{ij}$ .  $\gls{matrix}$   $\mathbf{I}$  is the
      identity  $\gls{matrix}$ .
4
5   \item A set, denoted as  $\gls{not:set}$ , is a collection of objects.
6
7   \item The universal set, denoted as  $\gls{not:universalSet}$ , is the
      set of everything.
8
9   \item The empty set, denoted as  $\gls{not:emptySet}$ , contains no
      elements.
10
11   \item The cardinality of a set, denoted as  $\gls{not:cardinality}$ , is
      the number of elements in the set.
12
13 \end{itemize}

```



1222

**B5 Figure**

1223

1224

This section shows several ways of placing figures. PDFL<sup>A</sup>T<sub>E</sub>X compatible files are PDF, PNG, and JPG. Please see the `figure` subdirectory.

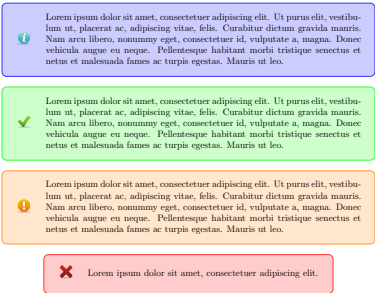


Fig. B.1 A quadrilateral image example.



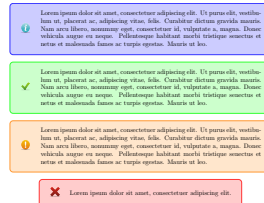
1225 Fig. B.1 is a gray box enclosed by a dark border. List. B.5 shows the corresponding  
1226  $\text{\LaTeX}$  code.

Listing B.5: Sample  $\text{\LaTeX}$  code for a single figure

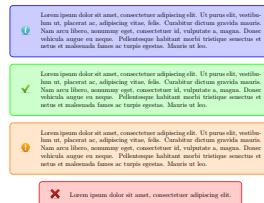
```
1 \begin{figure}[!htbp]
2   \centering
3   \includegraphics[width=0.5\textwidth]{example}
4   \caption{A quadrilateral image example.}
5   \label{fig:example}
6 \end{figure}
7 \cleardoublepage
8
9 Fig.~\ref{fig:example} is a gray box enclosed by a dark border. List.~\ref{lst:onefig} shows the corresponding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



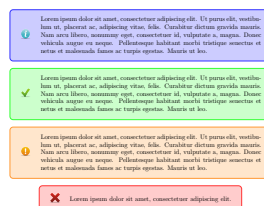
# De La Salle University



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



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

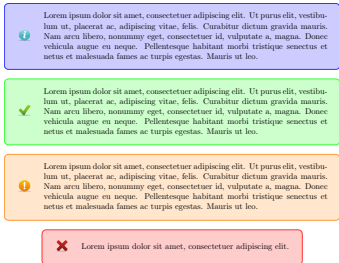


(c) A sub-figure in the bottom row.

Listing B.6: Sample L<sup>A</sup>T<sub>E</sub>X code for three figures on top of each other

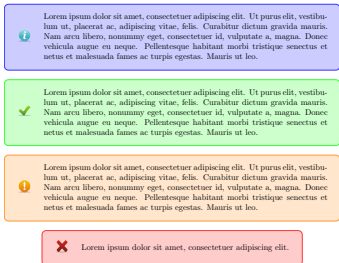
```
1 \begin{figure}[!htbp]
2 \centering
3 \subbottom[A sub-figure in the top row.]{
4 \includegraphics[width=0.35\textwidth]{example}
5 \label{fig:top}
6 }
7 \vfill
8 \subbottom[A sub-figure in the middle row.]{
9 \includegraphics[width=0.35\textwidth]{example}
10 \label{fig:mid}
11 }
12 \vfill
13 \subbottom[A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

B. Usage Examples



(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. B.3 Four figures in each corner. See List. B.7 for the corresponding  $\text{\LaTeX}$  code.



Listing B.7: Sample  $\text{\LaTeX}$  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}
5 \label{fig:upprleft}
6 }
7 \hfill
8 \subbottom[A sub-figure in the upper-right corner.]{
9 \includegraphics[width=0.45\textwidth]{example}
10 \label{fig:uppright}
11 }
12 \vfill
13 \subbottom[A sub-figure in the lower-left corner.]{
14 \includegraphics[width=0.45\textwidth]{example}
15 \label{fig:lowerleft}
16 }
17 \hfill
18 \subbottom[A sub-figure in the lower-right corner]{
19 \includegraphics[width=0.45\textwidth]{example}
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}

```



1227

**B6 Table**

1228

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

TABLE B.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)



1230

List. B.8 shows the corresponding  $\text{\LaTeX}$  code.Listing B.8: Sample  $\text{\LaTeX}$  code for making typical table environment

```

1231 1 \begin{center}
1232 2 {\scriptsize
1233 3 \begin{tabularx}{\textwidth}{p{0.1\textwidth}|p{0.2\textwidth}|p{0.5\textwidth}}
1234 4 \caption{Feasible triples for highly variable grid} \label{tab:triple_
1235 5 grid} \\
1236 6 \hline
1237 7 \textbf{Time (s)} &
1238 8 \textbf{Triple chosen} &
1239 9 \textbf{Other feasible triples} \\
1240 10 \hline
1241 11 \endfirsthead
1242 12 \multicolumn{3}{c}{\textit{Continued from previous page}} \\
1243 13 \hline
1244 14 \hline
1245 15 \textbf{Time (s)} &
1246 16 \textbf{Triple chosen} &
1247 17 \textbf{Other feasible triples} \\
1248 18 \hline
1249 19 \endhead
1250 20 \hline
1251 21 \multicolumn{3}{r}{\textit{Continued on next page}} \\
1252 22 \endfoot
1253 23 \hline
1254 24 \endlastfoot
1255 25 \hline
1256 26
1257 27
1258 28 0 & (1, 11, 13725) & (1, 12, 10980), (1, 13, 8235), (2, 2, 0), (3, 1, 0) \\
1259 29 & \\
1260 30 2745 & (1, 12, 10980) & (1, 13, 8235), (2, 2, 0), (2, 3, 0), (3, 1, 0) \\
1261 31 & \\
1262 32 5490 & (1, 12, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1263 33 8235 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1264 34 10980 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1265 35 13725 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1266 36 16470 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1267 37 19215 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1268 38 21960 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1269 39 24705 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1270 40 27450 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1271 41 30195 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
1272 42 32940 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1273 43 35685 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1274 44 38430 & (1, 13, 10980) & (2, 2, 2745), (2, 3, 0), (3, 1, 0)

```



```

1285 43 41175 & (1, 12, 13725) & (1, 13, 10980), (2, 2, 2745), (2, 3, 0), (3, 1,
1286      0) \\
1287 44 43920 & (1, 13, 10980) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1288 45 46665 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
1289 46 49410 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
1290 47 52155 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1,
1291      0) \\
1292 48 54900 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1293 49 57645 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1294 50 60390 & (1, 12, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1295 51 63135 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1296 52 65880 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1297 53 68625 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
1298 54 71370 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1299 55 74115 & (1, 12, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1300 56 76860 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1301 57 79605 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1302 58 82350 & (1, 12, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1303 59 85095 & (1, 12, 13725) & (1, 13, 10980), (2, 2, 2745), (2, 3, 0), (3, 1,
1304      0) \\
1305 60 87840 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1306 61 90585 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1307 62 93330 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1308 63 96075 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1309 64 98820 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1310 65 101565 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1311 66 104310 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1312 67 107055 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1313 68 109800 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1314 69 112545 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3,
1315      1, 0) \\
1316 70 115290 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1317 71 118035 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1318 72 120780 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1319 73 123525 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1320 74 126270 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3,
1321      1, 0) \\
1322 75 129015 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
1323 76 131760 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
1324 77 134505 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1325 78 137250 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1326 79 139995 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
1327 80 142740 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
1328 81 145485 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3,
1329      1, 0) \\
1330 82 148230 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
1331 83 150975 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1332 84 153720 & (1, 12, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1333 85 156465 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1334 86 159210 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1335 87 161955 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1336 88 164700 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1337 89 \end{tabularx}
1338 90 }
1339 91 \end{center}

```



1341

**B7 Algorithm or Pseudocode Listing**

1342

Table B.2 shows an example pseudocode. Note that if the pseudocode exceeds one page, it can mean that its implementation is not modular. List. B.9 shows the corresponding L<sup>A</sup>T<sub>E</sub>X code.

1343

1344

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

<b>Input(s):</b>	
$n$	: $n$ th power; $n \in \mathbb{Z}^+$
$x$	: base value; $x \in \mathbb{R}^+$
<b>Output(s):</b>	
$y$	: 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 { $N$  is odd}
14:     $y \leftarrow y \times X$ 
15:     $N \leftarrow N - 1$ 
16:  end if
17: end while
```

Listing B.9: Sample L<sup>A</sup>T<sub>E</sub>X 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}

```



## B8 Program/Code Listing

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

Listing B.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 */

```





1348

List. B.11 shows the corresponding  $\text{\LaTeX}$  code.

Listing B.11: Sample  $\text{\LaTeX}$  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.
```



## B9 Referencing

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

Referencing sections: This section is Sec. B9, which shows how to refer to the locations of various labels that have been placed in the  $\LaTeX$  files. List. B.12 shows the corresponding  $\LaTeX$  code.

Listing B.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.
```

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## B9.1 A subsection

Referencing subsections: This section is Sec. B9.1, which shows how to refer to a subsection. List. B.13 shows the corresponding  $\LaTeX$  code.

Listing B.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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### B9.1.1 A sub-subsection

Referencing sub-subsections: This section is Sec. B9.1.1, which shows how to refer to a sub-subsection. List. B.14 shows the corresponding  $\LaTeX$  code.

#### Listing B.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.
```

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## B10 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. B.15 is a program listing of the above-mentioned paragraph.

Listing B.15: Sample  $\text{\LaTeX}$  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.
```



## B11 Adding Relevant PDF Pages (e.g. Standards, Datasheets, Specification Sheets, Application Notes, etc.)

Selected PDF pages can be added (see List. B.16), but note that the options must be tweaked. See the manual of `pdfpages` for other options.

Listing B.16: Sample  $\text{\LaTeX}$  code for including PDF pages

```
1 \includepdf[pages={8-10},%
2 offset=3.5mm -10mm,%
3 scale=0.73,%
4 frame]
5 {./reference/Xilinx2015-UltraScaleArchitectureOverview.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 <sup>(1)</sup>	468	780	780	780	650	650	1,404
Maximum HR I/Os <sup>(2)</sup>	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 <sup>(1)(2)(3)</sup>	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 <sup>(1)</sup>	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 <sup>(1)(2)(3)</sup>	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 <sup>(4)</sup>						832, 52
FLVB2104	47.5x47.5		702, 76	702, 76	702, 76	624, 76	
FHVB2104	52.5x52.5 <sup>(4)</sup>						702, 76
FLVC2104	47.5x47.5		416, 80	416, 80	416, 104	416, 96	
FHVC2104	52.5x52.5 <sup>(4)</sup>						416, 104
FLVA2577	52.5x52.5				448, 120	448, 96	448, 128

**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 devices with the same sequence. The footprint compatible devices within this family are outlined.
4. 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 C

### PUBLICATION LIST AND AWARD

#### Journal

1. ...

2. ...

#### Conference

1. ...

2. ...



# De La Salle University

1413

## Others

1414

1. ...

1415

2. ...

1416

## Award

1417

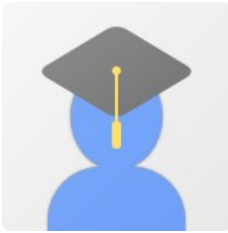
1. ...

1418

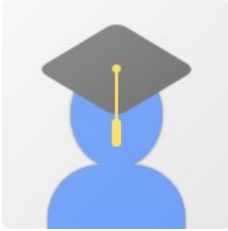
2. ...



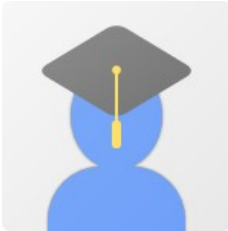
## Appendix D VITA



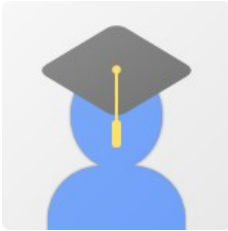
Junlae Cheong is a fifth year student at De La Salle University. He is currently taking up B.Sc. Computer Engineering . His strengths in the field are electronics circuit design and configuration. His fields of interest are electronics hardware and computer microprocessor.



Rohit P. Nihalani is a third year student at De La Salle University. He is currently taking up B.Sc. Computer Engineering . He has designed communication systems which covers basic AM radios. His fields of interest are digital communications and computer networks.



Noel B. Paulino is a third year student at De La Salle University, currently taking up B.Sc. Computer Engineering . His strengths in the field are microcontroller circuit design and advanced electronics.



Ryback Tyrone G. Po is a fourth year student at De La Salle University, currently taking up B.Sc. Computer Engineering . He has designed and programmed



1434

1435

electronic circuits that includes microcontrollers. His strengths in the field are microcontroller simulation and programming.



## INDEX

1436	contributions, 28
1437	Fourier operator, 70
1438	Fredholm integral, 70
1439	summary, 4