A Microcontroller-based System Used to Measure Different Weather Parameters Such As

Temperature, Humidity, and Amount of Rainfall

———————————

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 Computer Engineering

———————————

by

CHEONG, Junlae
NIHALANI, Rohit P.
PAULINO, Noel B.
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**.

Engr. Donabel D. Abuan
Adviser

May 27, 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:

CHEONG, Junlae
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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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Chair

Engr. Blanca I. Bucao
Member

Dr. Rionel B. Caldo
Member

Engr. Donabel D. Abuan
Adviser

Date: May 27, 2016

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64 **ACKNOWLEDGMENT**

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

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ABSTRACT

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

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

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TABLE OF CONTENTS

De La Salle University

De La Salle University

LIST OF FIGURES

De La Salle University

LIST OF TABLES

De La Salle University

ABBREVIATIONS

NOTATION

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 $\sin\left(\cdot\right)$. Commonly used notations are t, f, $\mathrm{j} = \sqrt{-1}$, n and $\exp\left(\cdot\right)$, which refer to the time variable, frequency variable, imaginary unit, nth variable, and exponential function, respectively.

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GLOSSARY

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LISTINGS

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Chapter 1

INTRODUCTION

Contents

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1.1 Background of the Study

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1.3 Problem Statement

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1.4 Objectives

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 scope in one group, and then bulletize the delimitations in another. Bulletize your assumptions as well.

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

LITERATURE REVIEW

Contents

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Cite and summarize here relevant and significant literature (dissertations, theses, journals, patents, notable conference papers) to prove that no one has done your work yet.

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376

2.1 Summary

Chapter 3

THEORETICAL CONSIDERATIONS

Contents

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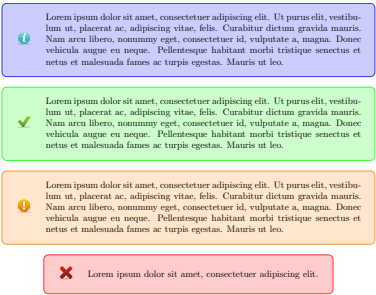
3.1 Summary

Fig. 3.1   A quadrilateral image example.

429 **Chapter 4**

430 # DESIGN CONSIDERATIONS

431 **Contents**

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480 ## 4.1   Summary

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Chapter 5

METHODOLOGY

Contents

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5.1   Implementation

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5.3   Summary

Chapter 6

RESULTS AND DISCUSSION

Contents

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6.1 Summary

Chapter 7

CONCLUSIONS, RECOMMENDATIONS, AND FUTURE DIRECTIVES

Contents

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7.1 Concluding Remarks

644

645 In this Thesis, . . .

7.2 Contributions

646

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

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7.3 Recommendations

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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 . . . .

2. the . . . .

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 LaTeX 2ε Or LaTeX 2ε in 157 minutes.* n.a.

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Appendix A
ANSWERS TO QUESTIONS TO THIS THESIS

Contents

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

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

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A2.1.3   How significant are your measure/s of the improvement/s?

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A3   What is the difference of the solution/s from existing ones?

Lorem ipsum dolor sit amet, consectetuer 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, consectetuer 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.

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

Lorem ipsum dolor sit amet, consectetuer 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, consectetuer 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.

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

Lorem ipsum dolor sit amet, consectetuer 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, consectetuer 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.

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A4.1 Will your proposed solution/s be sensitive to these assumptions?

Lorem ipsum dolor sit amet, consectetuer 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, consectetuer 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.

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

Lorem ipsum dolor sit amet, consectetuer 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, consectetuer 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.

A5 What is the necessity of your approach / proposed solution/s?

Lorem ipsum dolor sit amet, consectetuer 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, consectetuer 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.

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Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit amet ipsum. Nunc quis urna dictum turpis accumsan semper.

A5.1 What will be the limits of applicability of your proposed solution/s?

Lorem ipsum dolor sit amet, consectetuer 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, consectetuer 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.

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

Lorem ipsum dolor sit amet, consectetuer 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, consectetuer 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.

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

Lorem ipsum dolor sit amet, consectetuer 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, consectetuer adipiscing elit. Duis fringilla

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902 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue
903 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.
904 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit
905 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

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

908 Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Etiam lobortis facilisis sem.
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, consectetuer 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.

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

919 Lorem ipsum dolor sit amet, consectetuer 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, consectetuer 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.

A7.1 Can you come up with illustrating examples, or even better, counter examples to your proposed solution/s?

930 Lorem ipsum dolor sit amet, consectetuer 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.

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934 Praesent in sapien. Lorem ipsum dolor sit amet, consectetuer 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.

A7.2 Is there an approximation that can arrive at the essentially the same proposed solution/s more easily?

941 Lorem ipsum dolor sit amet, consectetuer 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, consectetuer 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.

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

952 Lorem ipsum dolor sit amet, consectetuer 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, consectetuer 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.

A8.1 What are the weaknesses of your proposal?

962 Lorem ipsum dolor sit amet, consectetuer 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, consectetuer 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.

971 # Appendix B
972 # USAGE EXAMPLES

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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.

B1   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 (B.1), the output signal $y(t)$ is the result of the convolution of the input signal $x(t)$ and the impulse response $h(t)$.

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

Other example equations are as follows.

$$\begin{bmatrix} V_1 \\ I_1 \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} V_2 \\ I_2 \end{bmatrix} \tag{B.2}$$

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

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

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986   The verbatim LaTeX code of Sec. B1 is in List. B.1.

Listing B.1: Sample 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}\left(\left\lfloor {y \over 17} \
        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  | \zeta(x)^3\zeta(x+iy)^4\zeta(x+2iy) | =
28  \exp\sum_{n,p}\frac{3+4\cos(ny\log p) +\cos (2ny\log p)}{np^{nx}}\ge 1
29  \end{eqnarray}
```

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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.

mathnormal	$A, B, \Gamma, \Delta, \Theta, \Lambda, \Xi, \Pi, \Sigma, \Phi, \Psi, \Omega, \alpha, \beta, \pi, \nu, \omega, v, w, 0, 1, 9$
mathit	$A, B, \Gamma, \Delta, \Theta, \Lambda, \Xi, \Pi, \Sigma, \Phi, \Psi, \Omega, \text{ff}, \text{fi}, \text{ß}, °, !, v, w, 0, 1, 9$
mathrm	$\text{A}, \text{B}, \Gamma, \Delta, \Theta, \Lambda, \Xi, \Pi, \Sigma, \Phi, \Psi, \Omega, \text{ff}, \text{fi}, \text{ß}, °, !, \text{v}, \text{w}, 0, 1, 9$
mathbf	$\mathbf{A}, \mathbf{B}, \boldsymbol{\Gamma}, \boldsymbol{\Delta}, \boldsymbol{\Theta}, \boldsymbol{\Lambda}, \boldsymbol{\Xi}, \boldsymbol{\Pi}, \boldsymbol{\Sigma}, \boldsymbol{\Phi}, \boldsymbol{\Psi}, \boldsymbol{\Omega}, \mathbf{ff}, \mathbf{fi}, \mathbf{ß}, °, !, \mathbf{v}, \mathbf{w}, \mathbf{0}, \mathbf{1}, \mathbf{9}$
mathsf	$\mathsf{A}, \mathsf{B}, \mathsf{\Gamma}, \mathsf{\Delta}, \mathsf{\Theta}, \mathsf{\Lambda}, \mathsf{\Xi}, \mathsf{\Pi}, \mathsf{\Sigma}, \mathsf{\Phi}, \mathsf{\Psi}, \mathsf{\Omega}, \mathsf{ff}, \mathsf{fi}, \mathsf{ß}, °, !, \mathsf{v}, \mathsf{w}, \mathsf{0}, \mathsf{1}, \mathsf{9}$
mathtt	$\mathtt{A}, \mathtt{B}, \mathtt{\Gamma}, \mathtt{\Delta}, \mathtt{\theta}, \mathtt{\Lambda}, \mathtt{\Xi}, \mathtt{\Pi}, \mathtt{\Sigma}, \mathtt{\Phi}, \mathtt{\Psi}, \mathtt{\Omega}, \uparrow, \downarrow, \mathtt{ß}, °, !, \mathtt{v}, \mathtt{w}, \mathtt{0}, \mathtt{1}, \mathtt{9}$

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

mathbfit	$\boldsymbol{A}, \boldsymbol{B}, \boldsymbol{\Gamma}, \boldsymbol{\Delta}, \boldsymbol{\Theta}, \boldsymbol{\Lambda}, \boldsymbol{\Xi}, \boldsymbol{\Pi}, \boldsymbol{\Sigma}, \boldsymbol{\Phi}, \boldsymbol{\Psi}, \boldsymbol{\Omega}, \boldsymbol{\alpha}, \boldsymbol{\beta}, \boldsymbol{\pi}, \boldsymbol{\nu}, \boldsymbol{\omega}, \boldsymbol{v}, \boldsymbol{w}, \mathbf{0}, \mathbf{1}, \mathbf{9}$
mathsfit	$A, B, \Gamma, \Delta, \Theta, \Lambda, \Xi, \Pi, \Sigma, \Phi, \Psi, \Omega, \alpha, \beta, \pi, \nu, \omega, v, w, 0, 1, 9$
mathsfbfit	$\boldsymbol{A}, \boldsymbol{B}, \boldsymbol{\Gamma}, \boldsymbol{\Delta}, \boldsymbol{\Theta}, \boldsymbol{\Lambda}, \boldsymbol{\Xi}, \boldsymbol{\Pi}, \boldsymbol{\Sigma}, \boldsymbol{\Phi}, \boldsymbol{\Psi}, \boldsymbol{\Omega}, \boldsymbol{\alpha}, \boldsymbol{\beta}, \boldsymbol{\pi}, \boldsymbol{\nu}, \boldsymbol{\omega}, \boldsymbol{v}, \boldsymbol{w}, \boldsymbol{0}, \boldsymbol{1}, \boldsymbol{9}$

Do the math alphabets match?
$$ax\alpha\omega\boldsymbol{ax\alpha\omega}ax\alpha\omega \quad \mathsf{TC\Theta\Gamma}\mathsf{TC\Theta}\boldsymbol{\Gamma}TC\Theta\Gamma$$

Vector symbols

Alphabetic symbols for vectors are boldface italic, $\boldsymbol{\lambda} = \boldsymbol{e}_1 \cdot \boldsymbol{a}$, while numeric ones (e.g. the zero vector) are bold upright, $\boldsymbol{a} + \mathbf{0} = \boldsymbol{a}$.

Matrix symbols

Symbols for matrices are boldface italic, too:[1] $\boldsymbol{\Lambda} = \boldsymbol{E} \cdot \boldsymbol{A}$.

---

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

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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:

$$\boldsymbol{D} = \epsilon_0 \boldsymbol{\epsilon}_{\mathrm{r}} \boldsymbol{E}$$

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Bold math version

1004

1005 The "bold" math version is selected with the commands `\boldmath` or `\mathversion{bold}`

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

1006 New alphabets bold-italic, sans-serif-italic, and sans-serif-bold-italic.

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

1007 Do the math alphabets match?

1008 $\quad ax\alpha\omega ax\alpha\omega ax\alpha\omega \quad TC\Theta\Gamma TC\Theta\Gamma TC\Theta\Gamma$

Vector symbols

1010 Alphabetic symbols for vectors are boldface italic, $\boldsymbol{\lambda} = \boldsymbol{e_1} \cdot \boldsymbol{a}$, while numeric ones (e.g.

1011 the zero vector) are bold upright, $\boldsymbol{a} + \mathbf{0} = \boldsymbol{a}$.

Matrix symbols

1013 Symbols for matrices are boldface italic, too:[2] $\boldsymbol{\Lambda} = \boldsymbol{E} \cdot \boldsymbol{A}.$

Tensor symbols

1015 Symbols for tensors are sans-serif bold italic,

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

1016 The permittivity tensor describes the coupling of electric field and displacement:

$$\boldsymbol{D} = \epsilon_0 \epsilon_{\mathrm{r}} \boldsymbol{E}$$

1017

---

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

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The verbatim LaTeX code of Sec. B2 is in List. B.2.

Listing B.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} &  & \teststring \\
26  \mbox{mathit} &  & \mathit{\teststring}\\
27  \mbox{mathrm} &  & \mathrm{\teststring}\\
28  \mbox{mathbf} &  & \mathbf{\teststring}\\
29  \mbox{mathsf} &  & \mathsf{\teststring}\\
30  \mbox{mathtt} &  & \mathtt{\teststring}
31  \end{eqnarray*}
32   New alphabets bold-italic, sans-serif-italic, and sans-serif-bold-
        italic.
33  \begin{eqnarray*}
34  \mbox{mathbfit}    &  & \mathbfit{\teststring}\\
35  \mbox{mathsfit}    &  & \mathsfit{\teststring}\\
36  \mbox{mathsfbfit} &  & \mathsfbfit{\teststring}
37  \end{eqnarray*}
38  %
39  Do the math alphabets match?
40
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
```

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```
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        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   $\matrixsym{\Lambda}=\matrixsym{E}\cdot\matrixsym{A}.$
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   \[
1094   73       \tensorsym{\alpha}  =  \tensorsym{e}\cdot\tensorsym{a}
1095   74       \quad \Longleftrightarrow \quad
1096   75       \alpha_{ijl}  =  e_{ijk}\cdot a_{kl}.
1097   76   \]
1098   77
1099   78
1100   79   The permittivity tensor describes the coupling of electric field and
1101   80   displacement: \[
1102   81   \vec{D}=\epsilon_{0}\tensorsym{\epsilon}_{\mathrm{r}}\vec{E}\]
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       \mbox{mathnormal} &  & \teststring \\
1115   94       \mbox{mathit} &  & \mathit{\teststring}\\
1116   95       \mbox{mathrm} &  & \mathrm{\teststring}\\
1117   96       \mbox{mathbf} &  & \mathbf{\teststring}\\
1118   97       \mbox{mathsf} &  & \mathsf{\teststring}\\
1119   98       \mbox{mathtt} &  & \mathtt{\teststring}
1120   99       \end{eqnarray*}
1121   100      New alphabets bold-italic, sans-serif-italic, and sans-serif-bold-
1122        italic.
1123   101      \begin{eqnarray*}
1124   102      \mbox{mathbfit}    &  & \mathbfit{\teststring}\\
1125   103      \mbox{mathsfit}    &  & \mathsfit{\teststring}\\
1126   104      \mbox{mathsfbfit} &  & \mathsfbfit{\teststring}
1127   105      \end{eqnarray*}
1128   106      %
1129   107      Do the math alphabets match?
```

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```
1130    108
1131    109       $
1132    110       \mathnormal  {a x \alpha \omega}
1133    111       \mathbfit    {a x \alpha \omega}
1134    112       \mathsfbfit{a x \alpha \omega}
1135    113       \quad
1136    114       \mathsfbfit{T C \Theta \Gamma}
1137    115       \mathbfit    {T C \Theta \Gamma}
1138    116       \mathnormal  {T C \Theta \Gamma}
1139    117       $
1140    118
1141    119       \subsection*{Vector symbols}
1142    120
1143    121       Alphabetic symbols for vectors are boldface italic,
1144    122       $\vec{\lambda}=\vec{e}_{1}\cdot\vec{a}$,
1145    123       while numeric ones (e.g. the zero vector) are bold upright,
1146    124       $\vec{a} + \vec{0} = \vec{a}$.
1147    125
1148    126
1149    127
1150    128
1151    129       \subsection*{Matrix symbols}
1152    130
1153    131       Symbols for matrices are boldface italic, too:%
1154    132       \footnote{However, matrix symbols are usually capital letters whereas
1155              vectors
1156    133       are small ones. Exceptions are physical quantities like the force
1157    134       vector $\vec{F}$ or the electrical field $\vec{E}$.%
1158    135       }
1159    136       $\matrixsym{\Lambda}=\matrixsym{E}\cdot\matrixsym{A}.$
1160    137
1161    138
1162    139       \subsection*{Tensor symbols}
1163    140
1164    141       Symbols for tensors are sans-serif bold italic,
1165    142
1166    143       \[
1167    144           \tensorsym{\alpha}  =  \tensorsym{e}\cdot\tensorsym{a}
1168    145           \quad \Longleftrightarrow \quad
1169    146           \alpha_{ijl}  =  e_{ijk}\cdot a_{kl}.
1170    147       \]
1171    148
1172    149       The permittivity tensor describes the coupling of electric field and
1173    150       displacement: \[
1174    151       \vec{D}=\epsilon_{0}\tensorsym{\epsilon}_{\mathrm{r}}\vec{E}\]
1175    152     }
1176
```

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B3 Abbreviation

This section shows examples of the use of LATEXcommands 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).

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1206 • Provide your own link text: style sheet.

1207 The verbatim LATEX code of Sec. B3 is in List. B.3.

Listing B.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}
```

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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 $\mathbf{I}$ 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.

- 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. 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 $\mathbfit{A}$. 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{enumerate}
```

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B5 Figure

This section shows several ways of placing figures. PDFLATEX compatible files are PDF, PNG, and JPG. Please see the `figure` subdirectory.
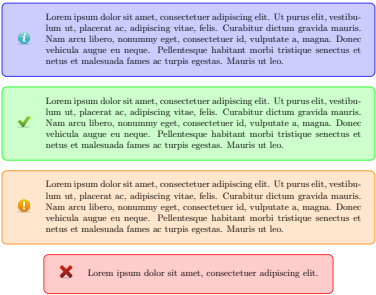
Fig. B.1   A quadrilateral image example.

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

Listing B.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 \LaTeX \ code.
10  \end{figure}
```

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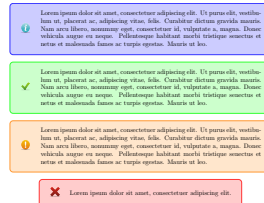
(a) A sub-figure in the top row.
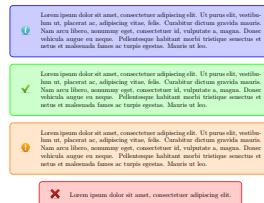
(b) A sub-figure in the middle row.

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

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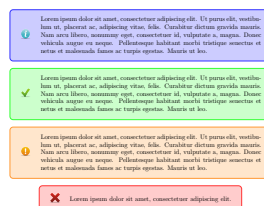
Listing B.6: Sample LATEX code for three figures on top of each other

```
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}
```

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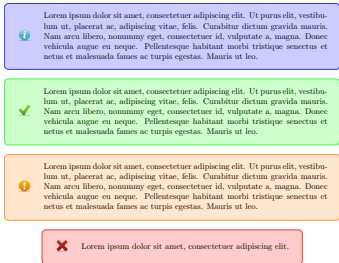
(b) A sub-figure in the upper-right corner.

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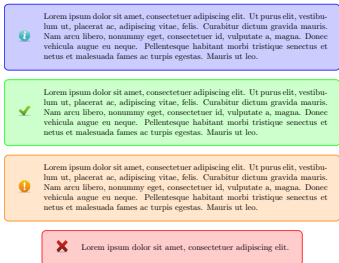
(d) A sub-figure in the lower-right corner

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

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Listing B.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}
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
       the corresponding \LaTeX \ code.}
23 \label{fig:fourfig}
24 \end{figure}
```

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B6   Table

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)

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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)

1229

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List. B.8 shows the corresponding LaTeX code.

Listing B.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}%
13  {\textit{Continued from previous page}} \\
14  \hline
15  \hline
16  \textbf{Time (s)} &
17  \textbf{Triple chosen} &
18  \textbf{Other feasible triples} \\
19  \hline
20  \endhead
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) \\
```

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```
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}
1340
```

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B7 Algorithm or Pseudocode Listing

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 LaTeX code.

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

Input(s):		
n	:	nth 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** $\{N$ is odd$\}$
14:         $y \Leftarrow y \times X$
15:         $N \Leftarrow N - 1$
16:     **end if**
17: **end while**

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Listing B.9: Sample LATEX code for algorithm or pseudocode listing usage

```latex
\begin{table}[!htbp]
    \caption{Calculation of $y = x^n$}
    \label{tab:calcxn}
    {\footnotesize
    \begin{tabular}{lll}
    \hline
    \hline
    {\bfseries Input(s):} & & \\
    $n$ & : & $n$th power; $n \in \mathbb{Z}^{+}$ \\
    $x$ & : & base value; $x \in \mathbb{R}^{+}$ \\
    \hline
    {\bfseries Output(s):} & & \\
    $y$ & : & result; $y \in \mathbb{R}^{+}$  \\
    \hline
    \hline
    \\
    \end{tabular}
    }
    \begin{algorithmic}[1]
    {\footnotesize
        \REQUIRE $n \geq 0 \vee x \neq 0$
        \ENSURE $y = x^n$
        \STATE $y \Leftarrow 1$
        \IF{$n < 0$}
                \STATE $X \Leftarrow 1 / x$
                \STATE $N \Leftarrow -n$
        \ELSE
                \STATE $X \Leftarrow x$
                \STATE $N \Leftarrow n$
        \ENDIF
        \WHILE{$N \neq 0$}
                \IF{$N$ is even}
                        \STATE $X \Leftarrow X \times X$
                        \STATE $N \Leftarrow N / 2$
                \ELSE[$N$ is odd]
                        \STATE $y \Leftarrow y \times X$
                        \STATE $N \Leftarrow N - 1$
                \ENDIF
        \ENDWHILE
    }
    \end{algorithmic}
\end{table}
```

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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 Fibonacci(I) \n\t====================\n");
20          next = current = 1;
21          for (i=1; i<=n; i++) {
22      printf("\t%d \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  */
```

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1348   List. B.11 shows the corresponding LaTeX code.

Listing B.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.
```

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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.
```

Lorem ipsum dolor sit amet, consectetuer 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, consectetuer 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.

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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

```
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.
```

Lorem ipsum dolor sit amet, consectetuer 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, consectetuer 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.

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B9.1.1   A sub-subsection

1376

1377 Referencing sub-subsections: This section is Sec. B9.1.1, which shows how to refer to a
1378 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.
```

1379 Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Etiam lobortis facilisis sem.
1380 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec
1381 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus
1382 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.
1383 Praesent in sapien. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Duis fringilla
1384 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue
1385 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.
1386 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit
1387 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

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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 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.
```

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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 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}
```

1402

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 HR, HP GTH, GTY	VU080 HR, HP GTH, GTY	VU095 HR, HP GTH, GTY	VU125 HR, HP GTH, GTY	VU160 HR, HP GTH, GTY	VU190 HR, HP GTH, GTY	VU440 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 HP, GTY	VU5P HP, GTY	VU7P HP, GTY	VU9P HP, GTY	VU11P HP, GTY	VU13P 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:
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. …

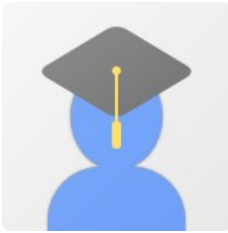## De La Salle University
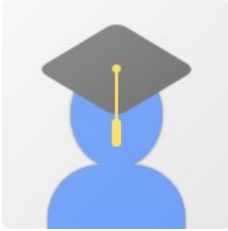
Others

1. ...
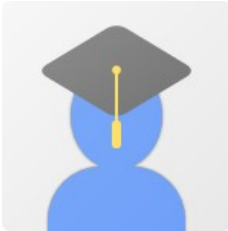
2. ...

Award

1. ...

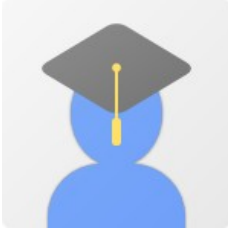2. ...

Appendix D
VITA

Junlae Cheong is a sixth year student at De La Salle University. He is currently taking up his B.Sc. Computer Engineering studies. 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 his B.Sc. Computer Engineering studies. He has designed communcation systems which covers basic AM radios. His fields of interest are digital communications and computer networks.

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

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1434 programmed electronic circuits that includes microcontrollers. His strengths in the field are
1435 microcontroller simulation and programming.

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INDEX