



Student Tracking System Using Radio Frequency Identification

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A Thesis Proposal  
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  
  
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UY, Charleston Franklin C.

May, 2016



De La Salle University

## ORAL DEFENSE RECOMMENDATION SHEET

This thesis proposal, entitled **Student Tracking System Using Radio Frequency Identification**, prepared and submitted by thesis group, ESG-04, composed of:

CASTILLO, Karlos Leo F.  
DEL ROSARIO, Aldwin Jocep C.  
JARABELO, Adrian Benjamin S.  
UY, Charleston Franklin C.

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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*Adviser*

May 30, 2016



De La Salle University

## THESIS PROPOSAL APPROVAL SHEET

This thesis proposal entitled **Student Tracking System Using Radio Frequency Identification**, prepared and submitted by:

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UY, Charleston Franklin C.

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 30, 2016



De La Salle University

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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 proposal.

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



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## ABBREVIATIONS

|     |      |                                  |    |
|-----|------|----------------------------------|----|
| 149 | AC   | Alternating Current.....         | 30 |
| 150 | CSS  | Cascading Style Sheet .....      | 30 |
| 151 | HTML | Hyper-text Markup Language ..... | 30 |
| 152 | XML  | eXtensible Markup Language ..... | 30 |



## NOTATION

153

|     |                 |   |    |
|-----|-----------------|---|----|
| 154 | $ \mathcal{S} $ | the number of elements in the set $\mathcal{S}$ ..... | 32 |
| 155 | $\emptyset$     | the set with no elements .....                        | 32 |
| 156 | $h(t)$          | impulse response .....                                | 22 |
| 157 | $\mathcal{S}$   | a collection of distinct objects .....                | 32 |
| 158 | $\mathcal{U}$   | the set containing everything .....                   | 32 |
| 159 | $x(t)$          | input signal represented in the time domain .....     | 22 |
| 160 | $y(t)$          | output signal represented in the time domain .....    | 22 |

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



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## GLOSSARY

168

matrix a concise and useful way of uniquely representing and working with linear transformations; a rectangular table of elements ..... 32



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## Chapter 1

### INTRODUCTION

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## 201 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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2. To ...;

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## 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

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

## 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

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## LITERATURE REVIEW

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

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





## 2.1 Summary



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Produced: May 30, 2016, 01:55



## Appendix A ANSWERS TO QUESTIONS TO THIS THESIS PROPOSAL

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

399 Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem.  
 400 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec  
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 407 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

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



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

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 431 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec  
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 438 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

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

440 Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem.  
 441 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec  
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449 **A2.1.3 How significant are your measure/s of the improvement/s?**

450 Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem.  
 451 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec  
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 458 amet ipsum. Nunc quis urna dictum turpis accumsan semper.



### **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?**

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

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

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

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

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

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

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

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

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

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528 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec  
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535 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

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

539 Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem.  
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547 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

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

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551 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec  
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557 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit  
558 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

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

561 Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem.  
562 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec  
563 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus  
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569 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

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

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

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

583 Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem.  
584 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec  
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590 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit  
591 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

## 592 **A7.2 Is there an approximation that can arrive at the essen-** 593 **tially the same proposed solution/s more easily?**

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595 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec  
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600 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.  
601 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit  
602 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

## 603 **A8 If you were the examiner of your proposal, how** 604 **would you present the proposal in another way?**

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

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

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



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



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625

## **Appendix B**

### **USAGE EXAMPLES**



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

## 629 B1 Equations

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

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

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

638 Other example equations are as follows.

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

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

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



639

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

Do the math alphabets match?

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

### 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  $\mathbf{E}$ .

654 **Tensor symbols**

655 Symbols for tensors are sans-serif bold italic,

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

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

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





## 657 Bold math version

658 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>     | $A, B, \Gamma, \Delta, \Theta, \Lambda, \Xi, \Pi, \Sigma, \Phi, \Psi, \Omega, \uparrow, \downarrow, \beta, ^\circ, !, v, w, 0, 1, 9$   |

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

660 Do the math alphabets match?

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

## 662 Vector symbols

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

## 665 Matrix symbols

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

## 667 Tensor symbols

668 Symbols for tensors are sans-serif bold italic,

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

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

$$D = \epsilon_0 \epsilon_r E$$

670

---

<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  $E$ .



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

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

```

672 1 % A teststring with Latin and Greek letters::
673 2 \newcommand{\teststring}{%
674 3 % capital Latin letters
675 4 % A,B,C,
676 5 A,B,
677 6 % capital Greek letters
678 7 %\Gamma,\Delta,\Theta,\Lambda,\Xi,\Pi,\Sigma,\Upsilon,\Phi,\Psi,
679 8 \Gamma,\Delta,\Theta,\Lambda,\Xi,\Pi,\Sigma,\Phi,\Psi,\Omega,
680 9 % small Greek letters
681 10 \alpha,\beta,\pi,\nu,\omega,
682 11 % small Latin letters:
683 12 % compare \nu, \omega, v, and w
684 13 v,w,
685 14 % digits
686 15 0,1,9
687 16 }
688 17
689 18
690 19 \subsection*{Math alphabets}
691 20
692 21 If there are other symbols in place of Greek letters in a math
693 22 alphabet, it uses T1 or OT1 font encoding instead of OML.
694 23
695 24 \begin{eqnarray*}
696 25 \mbox{\mathnormal} & & \mbox{\teststring} \\
697 26 \mbox{\mathit} & & \mbox{\mathit{\teststring}} \\
698 27 \mbox{\mathrm} & & \mbox{\mathrm{\teststring}} \\
699 28 \mbox{\mathbf} & & \mbox{\mathbf{\teststring}} \\
700 29 \mbox{\mathsf} & & \mbox{\mathsf{\teststring}} \\
701 30 \mbox{\mathtt} & & \mbox{\mathtt{\teststring}} \\
702 31 \end{eqnarray*}
703 32 New alphabets bold-italic, sans-serif-italic, and sans-serif-bold-
704 33 italic.
705 34 \begin{eqnarray*}
706 35 \mbox{\mathbfit} & & \mbox{\mathbfit{\teststring}} \\
707 36 \mbox{\mathsfit} & & \mbox{\mathsfit{\teststring}} \\
708 37 \mbox{\mathsfbfit} & & \mbox{\mathsfbfit{\teststring}} \\
709 38 \end{eqnarray*}
710 39 %
711 40 Do the math alphabets match?
712 41 $
713 42 \mathnormal {a x \alpha \omega}
714 43 \mathbfit {a x \alpha \omega}
715 44 \mathsfbfit{a x \alpha \omega}
716 45 \quad
717 46 \mathsfbfit{T C \Theta \Gamma}
718 47 \mathbfit {T C \Theta \Gamma}
719 48 \mathnormal {T C \Theta \Gamma}
720 49 $
721 50
722 51 \subsection*{Vector symbols}
723 52

```



```

726 53 Alphabetic symbols for vectors are boldface italic,  

727 54  $\vec{\lambda} = \vec{e}_1 \cdot \vec{a}$ ,  

728 55 while numeric ones (e.g. the zero vector) are bold upright,  

729 56  $\vec{a} + \vec{0} = \vec{a}$ .  

730 57  

731 58 \subsection*{Matrix symbols}  

732 59  

733 60 Symbols for matrices are boldface italic, too:%  

734 61 \footnote{However, matrix symbols are usually capital letters whereas  

735 62 vectors  

736 63 are small ones. Exceptions are physical quantities like the force  

737 64 vector  $\vec{F}$  or the electrical field  $\vec{E}$ .%  

738 65 }  

739 66  $\Lambda = E \cdot A$ .  

740 67  

741 68 \subsection*{Tensor symbols}  

742 69  

743 70 Symbols for tensors are sans-serif bold italic,  

744 71  

745 72 \[  

746 73   \text{\tensorsym{\alpha}} = \text{\tensorsym{e}} \cdot \text{\tensorsym{a}}  

747 74   \quad \Longleftrightarrow \quad  

748 75   \alpha_{ijl} = e_{ijk} \cdot a_{kl}.  

749 76 \]  

750 77  

751 78  

752 79 The permittivity tensor describes the coupling of electric field and  

753 80 displacement: \  

754 81  $D = \epsilon_0 \text{\tensorsym{\epsilon}}_{\text{\rm r}} \vec{E}$   

755 82  

756 83  

757 84  

758 85 \newpage  

759 86 \subsection*{Bold math version}  

760 87  

761 88 The ‘‘bold’’ math version is selected with the commands  

762 89 \verb+\boldmath+ or \verb+\mathversion{bold}+  

763 90  

764 91 {\boldmath  

765 92   \begin{eqnarray*}  

766 93     \mbox{\mathnormal} & & \teststring \\
767 94     \mbox{\mathit} & & \mathit{\teststring} \\
768 95     \mbox{\mathrm} & & \mathrm{\teststring} \\
769 96     \mbox{\mathbf} & & \mathbf{\teststring} \\
770 97     \mbox{\mathsf} & & \mathsf{\teststring} \\
771 98     \mbox{\mathtt} & & \mathtt{\teststring} \\
772 99   \end{eqnarray*}  

773 100   New alphabets bold-italic, sans-serif-italic, and sans-serif-bold-  

774 101   italic.  

775 102   \begin{eqnarray*}  

776 103     \mbox{\mathbfit} & & \mathbfit{\teststring} \\
777 104     \mbox{\mathsf fit} & & \mathsf fit{\teststring} \\
778 105     \mbox{\mathsf bfit} & & \mathsf bfit{\teststring} \\
779 106   \end{eqnarray*}  

780 107   %  

781 108   Do the math alphabets match?  

782 109

```



B. Usage Examples

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```
783 108 $
784 109 \mathnormal {a x \alpha \omega}
785 110 \mathbf{it} {a x \alpha \omega}
786 111 \mathsf{fbfit}{a x \alpha \omega}
787 112 \quad
788 113 \mathsf{fbfit}{T C \Theta \Gamma}
789 114 \mathbf{it} {T C \Theta \Gamma}
790 115 \mathnormal {T C \Theta \Gamma}
791 116 $
792 117
793 118 \subsection*{Vector symbols}
794 119
795 120 Alphabetic symbols for vectors are boldface italic,
796 121 $\vec{\lambda}=\vec{e}_1\cdot\vec{a}$,
797 122 while numeric ones (e.g. the zero vector) are bold upright,
798 123 $\vec{a} + \vec{0} = \vec{a}$.
799 124
800 125
801 126
802 127
803 128 \subsection*{Matrix symbols}
804 129
805 130 Symbols for matrices are boldface italic, too:%
806 131 \footnote[However, matrix symbols are usually capital letters whereas
807 132 vectors
808 133 are small ones. Exceptions are physical quantities like the force
809 134 vector $\vec{F}$ or the electrical field $\vec{E}$.%
810 135 }
811 136 $\matrixsym{\Lambda}=\matrixsym{E}\cdot\matrixsym{A}.$
812 137
813 138
814 139 \subsection*{Tensor symbols}
815 140
816 141 Symbols for tensors are sans-serif bold italic,
817 142
818 143 \[
819 144 \quad \quad \quad \matrixsym{\alpha} = \matrixsym{e}\cdot\matrixsym{a}
820 145 \quad \quad \quad \Longleftarrow \quad \quad \quad
821 146 \quad \quad \quad \alpha_{ijl} = e_{ijk}\cdot a_{kl}.
822 147 \]
823 148
824 149 The permittivity tensor describes the coupling of electric field and
825 150 displacement: \[
826 151 \vec{D}=\epsilon_0\matrixsym{\epsilon}_{\mathrm{r}}\vec{E}\]
827 152 }
```



## 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).



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

860 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 Proposal. 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}

```



875

**B5 Figure**

876

877

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.





878 Fig. B.1 is a gray box enclosed by a dark border. List. B.5 shows the corresponding  
879  $\text{\LaTeX}$  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}
```



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



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

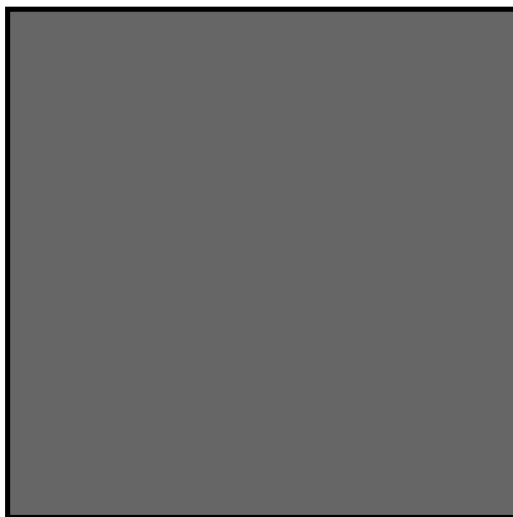


(c) A sub-figure in the bottom row.

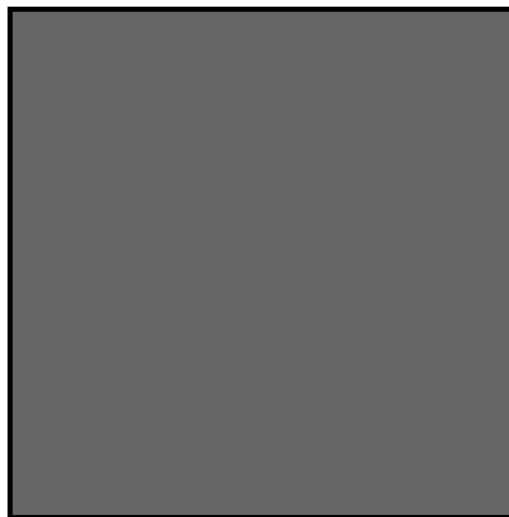
Fig. B.2 Figures on top of each other. See List. B.6 for the corresponding  $\text{\LaTeX}$  code.

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}
```



(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  $\LaTeX$  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}

```



880

**B6 Table**

881

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)                 |



883 List. B.8 shows the corresponding  $\text{\LaTeX}$  code.

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

```

884 1 \begin{center}
885 2 {\scriptsize
886 3 \begin{tabularx}{\textwidth}{p{0.1\textwidth}|p{0.2\textwidth}|p{0.5\textwidth}}
887 4 \caption{Feasible triples for highly variable grid} \label{tab:triple_
888 5 grid} \\
889 6 \hline
890 7 \textbf{Time (s)} &
891 8 \textbf{Triple chosen} &
892 9 \textbf{Other feasible triples} \\
893 10 \hline
894 11 \endfirsthead
895 12 \multicolumn{3}{c}{\textit{Continued from previous page}} \\
896 13 \hline
897 14 \hline
898 15 \textbf{Time (s)} &
899 16 \textbf{Triple chosen} &
900 17 \textbf{Other feasible triples} \\
901 18 \hline
902 19 \endhead
903 20 \hline
904 21 \hline
905 22 \multicolumn{3}{r}{\textit{Continued on next page}} \\
906 23 \endfoot
907 24 \hline
908 25 \endlastfoot
909 26 \hline
910 27
911 28 0 & (1, 11, 13725) & (1, 12, 10980), (1, 13, 8235), (2, 2, 0), (3, 1, 0) \\
912 29 & 2745 & (1, 12, 10980) & (1, 13, 8235), (2, 2, 0), (2, 3, 0), (3, 1, 0) \\
913 30 & 5490 & (1, 12, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
914 31 & 8235 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
915 32 & 10980 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
916 33 & 13725 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
917 34 & 16470 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
918 35 & 19215 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
919 36 & 21960 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
920 37 & 24705 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
921 38 & 27450 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
922 39 & 30195 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
923 40 & 32940 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
924 41 & 35685 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
925 42 & 38430 & (1, 13, 10980) & (2, 2, 2745), (2, 3, 0), (3, 1, 0)

```





```

938 43 41175 & (1, 12, 13725) & (1, 13, 10980), (2, 2, 2745), (2, 3, 0), (3, 1,
939 0) \\
940 44 43920 & (1, 13, 10980) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
941 45 46665 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
942 46 49410 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
943 47 52155 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1,
944 0) \\
945 48 54900 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
946 49 57645 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
947 50 60390 & (1, 12, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
948 51 63135 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
949 52 65880 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
950 53 68625 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
951 54 71370 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
952 55 74115 & (1, 12, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
953 56 76860 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
954 57 79605 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
955 58 82350 & (1, 12, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
956 59 85095 & (1, 12, 13725) & (1, 13, 10980), (2, 2, 2745), (2, 3, 0), (3, 1,
957 0) \\
958 60 87840 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
959 61 90585 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
960 62 93330 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
961 63 96075 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
962 64 98820 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
963 65 101565 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
964 66 104310 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
965 67 107055 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
966 68 109800 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
967 69 112545 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3,
968 1, 0) \\
969 70 115290 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
970 71 118035 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
971 72 120780 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
972 73 123525 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
973 74 126270 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3,
974 1, 0) \\
975 75 129015 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
976 76 131760 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
977 77 134505 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
978 78 137250 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
979 79 139995 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
980 80 142740 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
981 81 145485 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3,
982 1, 0) \\
983 82 148230 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
984 83 150975 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
985 84 153720 & (1, 12, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
986 85 156465 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
987 86 159210 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
988 87 161955 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
989 88 164700 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
990 89 \end{tabularx}
991 90 }
992 91 \end{center}

```



994

**B7    Algorithm or Pseudocode Listing**

995

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.

996

997

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 */

```



1001

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

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## Others

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## Award

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## Appendix D VITA



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# De La Salle University



Charleston Franklin C. Uy is a fourth year engineering student and currently taking up Bachelor of Science in Computer Engineering at De La Salle University - Manila, Philippines. He is knowledgeable in database systems, programming languages such as C, CSS, Java, HTML, MySQL, PHP and Verilog, and has developed several electronic circuits that utilizes the PIC microcontroller. His research interest includes automation, environment friendly technologies and radio frequency identification technologies.



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| 1096 | Fredholm integral, 50 |
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