



Home Power Management System using GSM with Electricity Billing Display with Bill
SMS feature

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

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June, 2016



De La Salle University

ORAL DEFENSE RECOMMENDATION SHEET

This thesis, entitled **Home Power Management System using GSM with Electricity Billing Display with Bill SMS feature**, prepared and submitted by thesis group, Ariba, composed of:

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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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THESIS APPROVAL SHEET

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ACKNOWLEDGMENT

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



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ABSTRACT

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

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



72

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ABBREVIATIONS

| | | | |
|-----|------|----------------------------------|----|
| 171 | AC | Alternating Current | 51 |
| 172 | HTML | Hyper-text Markup Language | 51 |
| 173 | CSS | Cascading Style Sheet | 51 |
| 174 | XML | eXtensible Markup Language | 51 |



175

NOTATION

| | | | |
|-----|-----------------|---|----|
| 176 | \mathcal{S} | a collection of distinct objects | 53 |
| 177 | \mathcal{U} | the set containing everything | 53 |
| 178 | \emptyset | the set with no elements | 53 |
| 179 | $ \mathcal{S} $ | the number of elements in the set \mathcal{S} | 53 |
| 180 | $h(t)$ | impulse response | 43 |
| 181 | $x(t)$ | input signal represented in the time domain | 43 |
| 182 | $y(t)$ | output signal represented in the time domain | 43 |

183 Throughout this thesis, mathematical notations conform to ISO 80000-2 standard, e.g.
184 variable names are printed in italics, the only exception being acronyms like e.g. SNR,
185 which are printed in regular font. Constants are also set in regular font like j . Functions are
186 also set in regular font, e.g. in $\sin(\cdot)$. Commonly used notations are t , f , $j = \sqrt{-1}$, n and
187 $\exp(\cdot)$, which refer to the time variable, frequency variable, imaginary unit, n th variable,
188 and exponential function, respectively.



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GLOSSARY

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matrix a concise and useful way of uniquely representing and working with linear transformations; a rectangular table of elements 53



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INTRODUCTION

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1.1 Background of the Study

The Home Power Management System using GSM with Electricity Billing Display with Bill SMS feature offers a way to access your home appliances through your phone anywhere you are. It uses a GSM receiver modem to receive information from the sender, in this case an SMS from the phone of the user, to manage the home appliances connected to the device. GSM is widely used as a global system for mobile communications, spanning Europe, Asia, Africa and much of South America. Most GSM modems use frequencies in the 900 MHz band and are able to receive signals through SMS, then output a maximum power of 1 to 8 Watts. A user can send SMS to the GSM modem to turn on/off the devices connected to it. An additional feature of monitoring your electric bill and status of each appliances connected to the device will be provided. The GSM modem will be connected to a main power controller where the other appliances are connected to be monitored, and are switched on and off by the user through their phone.

An additional improvement could be added by making an application to provide a user friendly GUI. Making it more visually appealing and easier for the user to check their bill, and status of each appliances. Additional features may be added such as a monitoring system if the appliance is broken, electrical consumption of each connected appliances. Additional information of each connected appliances (Brand, Model, Watt usage, etc.).

1.2 Prior Studies

According to the research done by Brush et al. (2011), home automation has not been widely adopted. Based on the study, it is because of the high cost of ownership, inflexibility, poor manageability, and difficulty in terms of security. Even though some of the experiences



245 of the users were negative, majority of the households that were visited by the researchers
 246 said that they had a positive experience about home automation. Most of the brands that
 247 was used in home automation includes the X10, Control4, Elk, M1, HAI, Creston, Lagotek,
 248 and Leviton. The products of the brands mentioned includes lighting controls, multi-
 249 room audio/video systems, security cameras, and motion detectors. Also, the researchers
 250 observed that there are two levels of automation in use. One is the user controlled while the
 251 other is rule-based. In user controlled automation, the home automation needs to have a
 252 command that needs to be done or said. On the other hand, rule-based automation does
 253 not require any external commands. The system is triggered by using motion sensors or by
 254 setting up the system to do an action that involves time.

255 In the present day, home automation can be done by using a mobile phone. A research
 256 conducted by Mahesh Jivani last 2014. Jivani (2014) stated that the Global System for
 257 Mobile Communication or the GSM and the use of cellular phones can be used for commu-
 258 nicating with other devices at a distance. It can be applied to the home automation by using
 259 the bluetooth and the Wi-Fi. Based on the research, an android phone can be used to send
 260 an SMS through the GSM network. After that, the modem receives the SMS which is then
 261 passed to the arduino microcontroller. After the microcontroller, the data is then sent to the
 262 peripheral drivers and the relays. Finally, the command is accepted by the appliances.

263 Internet Based Wireless Home Automation System for Multifunctional Devices was
 264 researched by Alkar and Buhur (2005). This paper features a low cost and flexible web-
 265 based solution to home automation. However, this system has some limitations such as the
 266 range of communication and power failure problems.

267 A Home Appliance Control System (HACS) was researched by Malik et al. (2009).
 268 The research focused on remotely controlling home appliances and at the same time offers



269 security when the owner is not near the place where the system was installed. They
270 proposed the usage of GSM technology to provide control from SMS that are sent from the
271 users mobile device. The use of SMS makes the system more convenient and accessible.
272 Security measures (e.g. Motion Sensors) that are installed within the place of choice may
273 also trigger the HACS to send SMS to the users mobile phone when intrusion occurs.

274 In the research paper by Conte and Scaradozzi (2003), the researchers view home
275 automation systems as multiple agent systems (MAS). The home automation system that
276 they proposed includes home appliances and devices that are controlled and maintained for
277 home management. The major task of their research is to improve the performance of the
278 current home automation systems that are available.

279 1.3 Problem Statement

280 The students want to monitor and know the amount of electricity used by appliances and
281 the correspondent cost. Also, being able to control the appliances through mobile devices
282 using GSM would be a part of the research. One of the main problem in the world today
283 is high electricity consumption and most of the users are clueless about the problem. The
284 world today revolves around the technology and electricity consumption plays a big role for
285 it. Most of the consumers and users do not know the cost of the electricity being consumed
286 not until the bill comes. But being able to see the cost and the amount electricity used, the
287 users will be able to control and lessen or lower electricity consumption. Energy saving is
288 a must because the resources we have today will not be enough for the next generation if
289 high electricity consumption is not solved.



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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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3. To ...;

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4. To ...;

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5. To ...;

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1.5 Significance of the Study

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In today's modern world of technology, high-tech appliances are every man's best friend in terms of convenience and . However, these instruments that make a person's life easier are subject to major discrepancies such as and most importantly high power usage due to its advanced specifications. This in turn would affect the amount of money a household should spend in order to compensate the expenses. For some families, it would be alright to leave the air conditioning and any other appliance on but for those that would like to budget their money, our study would be certainly useful.

307

In today's generation, it is highly unlikely that someone does not own a smart phone.

308

These mobiles take up so much of our time and attention that it is almost never not in our



309 hands. This norm is what drives the researchers into thinking that an SMS based study
 310 would be the most appropriate. By allowing a user easy access to turn on and off just by
 311 sending a text, we provide a platform for convenience.

312 Other than the SMS being a controlling system, it paves way to provide a monthly
 313 billing display sent to the user. The importance of this is that it would lessen the casualties
 314 of bills being tampered. This would be a great advantage to electricity companies in terms
 315 of its relation with the customers.

316 **1.6 Assumptions, Scope and Delimitations**

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

319 **1.7 Description and Methodology**

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1.8 Overview

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Provide here a brief summary and what the reader should expect from each succeeding

331

chapter. Show how each chapter are connected with each other.



332

Chapter 2

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LITERATURE REVIEW

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

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2.1 Summary



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Chapter 3

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THEORETICAL CONSIDERATIONS

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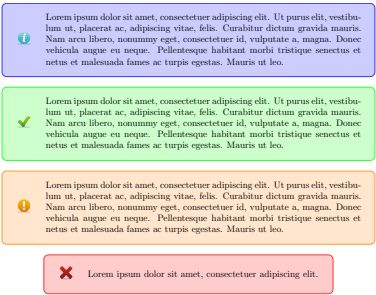


Fig. 3.1 A quadrilateral image example.



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Chapter 4

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DESIGN CONSIDERATIONS

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489 4.1 Summary



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Chapter 5

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METHODOLOGY

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5.1 Implementation

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5.2 Evaluation

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5.3 Summary



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Chapter 6

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RESULTS AND DISCUSSION

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642 6.1 Summary



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Chapter 7

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CONCLUSIONS, RECOMMENDATIONS,

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AND FUTURE DIRECTIVES

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7.1 Concluding Remarks

In this Thesis, . . .

7.2 Contributions

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

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- the ;

7.3 Recommendations

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707 **7.4 Future Prospects**

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

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711 2. the

712 3. the



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[Oetiker et al., 2014] Oetiker, T., Partl, H., Hyna, I., and Schlegl, E. (2014). *The Not So Short Introduction to L^AT_EX 2_ε Or L^AT_EX 2_ε in 157 minutes*. n.a.



Appendix A ANSWERS TO QUESTIONS TO THIS THESIS

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| A8.1 | What are the weaknesses of your proposal? | 40 |



754

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

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

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805 **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?

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

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

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

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

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

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

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

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

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

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

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

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948 **A7.2 Is there an approximation that can arrive at the essen-** 949 **tially the same proposed solution/s more easily?**

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959 **A8 If you were the examiner of your proposal, how** 960 **would you present the proposal in another way?**

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

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 972 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec
 973 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus
 974 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.



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



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Appendix B

USAGE EXAMPLES



The user is expected to have a working knowledge of \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 $h(t)$.

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

Other example equations are as follows.

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

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

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



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The verbatim L^AT_EX code of Sec. B1 is in List. B.1.Listing B.1: Sample L^AT_EX code for equations and notations usage

```

1 The following examples show how to typeset equations in \LaTeX.
2
3 In~\eqref{eq:conv}, the output signal \gls{not:output_sigt} is the
  result of the convolution of the input signal \gls{not:input_sigt}
  and the impulse response \gls{not:ir}.
4
5 \begin{eqnarray}
6   y\left( t \right) = h\left( t \right) * x\left( t \right)=\int_{-\infty}^{+\infty}h\left( t-\tau \right)x\left( \tau \right) \mathrm{d}\tau
7   \label{eq:conv}
8 \end{eqnarray}
9
10 Other example equations are as follows.
11
12 \begin{eqnarray}
13   \left[ \dfrac{V_{1}}{I_{1}} \right] =
14   \begin{bmatrix}
15     A & B \\
16     C & D
17   \end{bmatrix}
18   \left[ \dfrac{V_{2}}{I_{2}} \right]
19   \label{eq:ABCD}
20 \end{eqnarray}
21
22 \begin{eqnarray}
23   \{1\over 2\} < \left\lfloor \mathrm{mod}\right\left(\left\lfloor y \over 17\right\right\rfloor 2^{\{-17\lfloor x \rfloor - \mathrm{mod}(\lfloor y \rfloor, 17)\}}, 2\right)\right\rfloor,
24 \end{eqnarray}
25
26 \begin{eqnarray}
27   \left| \zeta(x)^3\zeta(x+iy)^4\zeta(x+2iy) \right| =
28   \exp\sum_{n,p}\frac{3+4\cos(ny\log p) +\cos(2ny\log p)}{n^p}\geq 1
29 \end{eqnarray}

```



B2 Notations

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

Math alphabets

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

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

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

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

Do the math alphabets match?

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

Vector symbols

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

Matrix symbols

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

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



1010

Tensor symbols

1011

Symbols for tensors are sans-serif bold italic,

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

1012

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

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



Bold math version

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

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

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

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

Do the math alphabets match?

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

Vector symbols

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

Matrix symbols

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

Tensor symbols

Symbols for tensors are sans-serif bold italic,

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

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

$$D = \epsilon_0 \epsilon_r E$$

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



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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

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```

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-
33   italic.
34 \begin{eqnarray*}
35 \mbox{\mathbfit} & & \& \& \mathbfit{\teststring} \\
36 \mbox{\mathsfbit} & & \& \& \mathsfbit{\teststring} \\
37 \mbox{\mathsfbfit} & & \& \& \mathsfbfit{\teststring}
38 \end{eqnarray*}
39 %
40 Do the math alphabets match?
41 $
42 \mathnormal {a x \alpha \omega}
43 \mathbfit {a x \alpha \omega}
44 \mathsfbfit{a x \alpha \omega}
45 \quad
46 \mathsfbfit{T C \Theta \Gamma}
47 \mathbfit {T C \Theta \Gamma}
48 \mathnormal {T C \Theta \Gamma}
49 $
50
51 \subsection*{Vector symbols}
52

```



```

1082 53 Alphabetic symbols for vectors are boldface italic,
1083 54  $\vec{\lambda} = \vec{e}_1 \cdot \vec{a}$ ,
1084 55 while numeric ones (e.g. the zero vector) are bold upright,
1085 56  $\vec{a} + \vec{0} = \vec{a}$ .
1086 57
1087 58 \subsection*{Matrix symbols}
1088 59
1089 60 Symbols for matrices are boldface italic, too:%
1090 61 \footnote{However, matrix symbols are usually capital letters whereas
1091 62 vectors
1092 62 are small ones. Exceptions are physical quantities like the force
1093 63 vector  $\vec{F}$  or the electrical field  $\vec{E}$ .%
1094 64 }
1095 65  $\mathbf{\Lambda} = \mathbf{E} \cdot \mathbf{A}$ .
1096 66
1097 67
1098 68 \subsection*{Tensor symbols}
1099 69
1100 70 Symbols for tensors are sans-serif bold italic,
1101 71
1102 72 \[
1103 73 \quad \mathbf{\alpha} = \mathbf{e} \cdot \mathbf{a}
1104 74 \quad \Longleftrightarrow
1105 75 \quad \alpha_{ijl} = e_{ijk} \cdot a_{kl}.
1106 76 \]
1107 77
1108 78
1109 79 The permittivity tensor describes the coupling of electric field and
1110 80 displacement: \[
1111 81 \mathbf{D} = \epsilon_0 \mathbf{\epsilon}(\mathbf{r}) \mathbf{E} \]
1112 82
1113 83
1114 84
1115 85 \newpage
1116 86 \subsection*{Bold math version}
1117 87
1118 88 The ‘‘bold’’ math version is selected with the commands
1119 89 \verb+\boldmath+ or \verb+\mathversion{bold}+
1120 90
1121 91 {\boldmath
1122 92 \begin{eqnarray*}
1123 93 \quad \mathbf{normal} & & \text{\texttt{\textbackslash teststring}} \\
1124 94 \quad \mathbf{hit} & & \text{\texttt{\textbackslash mathit{\textbackslash teststring}}} \\
1125 95 \quad \mathbf{rm} & & \text{\texttt{\textbackslash mathrm{\textbackslash teststring}}} \\
1126 96 \quad \mathbf{bf} & & \text{\texttt{\textbackslash mathbf{\textbackslash teststring}}} \\
1127 97 \quad \mathbf{sf} & & \text{\texttt{\textbackslash mathsf{\textbackslash teststring}}} \\
1128 98 \quad \mathbf{htt} & & \text{\texttt{\textbackslash mathtt{\textbackslash teststring}}} \\
1129 99 \end{eqnarray*}
1130 100 \quad \text{New alphabets bold-italic, sans-serif-italic, and sans-serif-bold-}
1131 101 \quad \text{italic.}
1132 102 \begin{eqnarray*}
1133 103 \quad \mathbf{bf} & & \text{\texttt{\textbackslash mathbf{\textbackslash teststring}}} \\
1134 104 \quad \mathbf{sf} & & \text{\texttt{\textbackslash mathsf{\textbackslash teststring}}} \\
1135 105 \quad \mathbf{bf} & & \text{\texttt{\textbackslash mathsfbf{\textbackslash teststring}}} \\
1136 106 \end{eqnarray*}
1137 107 \%
1138 108 Do the math alphabets match?

```




```

1139 108
1140 109 $
1141 110 \mathnormal {a x \alpha \omega}
1142 111 \mathbfit {a x \alpha \omega}
1143 112 \mathsfbfit{a x \alpha \omega}
1144 113 \quad
1145 114 \mathsfbfit{T C \Theta \Gamma}
1146 115 \mathbfit {T C \Theta \Gamma}
1147 116 \mathnormal {T C \Theta \Gamma}
1148 117 $
1149 118
1150 119 \subsection*{Vector symbols}
1151 120
1152 121 Alphabetic symbols for vectors are boldface italic,
1153 122 $\vec{\lambda}=\vec{e}_1\cdot\vec{a}$,
1154 123 while numeric ones (e.g. the zero vector) are bold upright,
1155 124 $\vec{a} + \vec{0} = \vec{a}$.
1156 125
1157 126
1158 127
1159 128
1160 129 \subsection*{Matrix symbols}
1161 130
1162 131 Symbols for matrices are boldface italic, too:%
1163 132 \footnote{However, matrix symbols are usually capital letters whereas
1164 133 vectors
1165 134 are small ones. Exceptions are physical quantities like the force
1166 135 vector $\vec{F}$ or the electrical field $\vec{E}$.%
1167 136 }
1168 136 $\matrixsym{\Lambda}=\matrixsym{E}\cdot\matrixsym{A}$.
1169 137
1170 138
1171 139 \subsection*{Tensor symbols}
1172 140
1173 141 Symbols for tensors are sans-serif bold italic,
1174 142
1175 143 \[
1176 144 \tensorsym{\alpha} = \tensorsym{e}\cdot\tensorsym{a}
1177 145 \quad \Longleftrightarrow \quad
1178 146 \alpha_{ijl} = e_{ijk}\cdot a_{kl}.
1179 147 \]
1180 148
1181 149 The permittivity tensor describes the coupling of electric field and
1182 150 displacement: \[
1183 151 \vec{D}=\epsilon_0\tensorsym{\epsilon}_{\mathrm{r}}\vec{E}\]
1184 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).



- 1215 • Provide your own link text: style sheet.

1216 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}

```



B4 Glossary

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

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

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

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

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

```

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

```



1231

B5 Figure

1232

1233

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

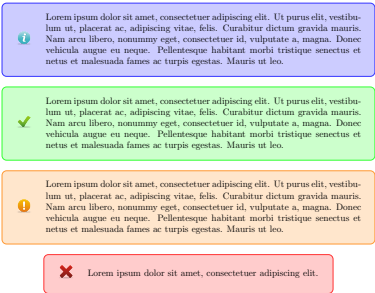


Fig. B.1 A quadrilateral image example.



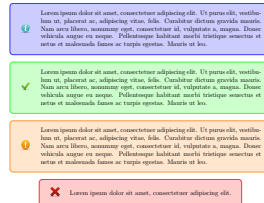
1234 Fig. B.1 is a gray box enclosed by a dark border. List. B.5 shows the corresponding
1235 L^AT_EX code.

Listing B.5: Sample L^AT_EX code for a single figure

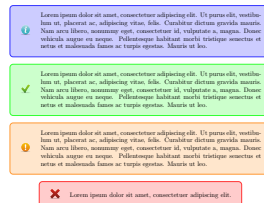
```
1 \begin{figure}[!htbp]
2   \centering
3   \includegraphics[width=0.5\textwidth]{example}
4   \caption{A quadrilateral image example.}
5   \label{fig:example}
6 \end{figure}
7 \cleardoublepage
8
9 Fig.~\ref{fig:example} is a gray box enclosed by a dark border. List.~\
  ref{lst:onefig} shows the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



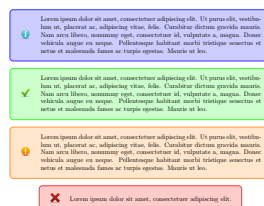
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(a) A sub-figure in the top row.



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

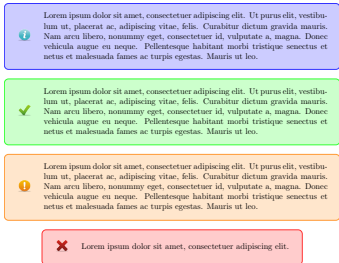


(c) A sub figure in the bottom row

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

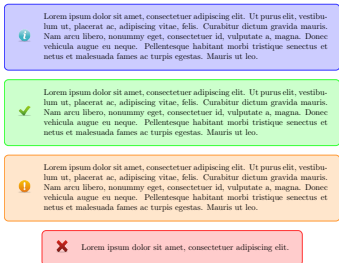
```
1 \begin{figure}[!htbp]
2 \centering
3 \subbottom[A sub-figure in the top row.]{
4 \includegraphics[width=0.35\textwidth]{example}
5 \label{fig:top}
6 }
7 \vfill
8 \subbottom[A sub-figure in the middle row.]{
9 \includegraphics[width=0.35\textwidth]{example}
10 \label{fig:mid}
11 }
12 \vfill
13 \subbottom[A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


B. Usage Examples



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

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



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

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

Fig. B.3 Four figures in each corner. See List. B.7 for the corresponding \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}

```



1236

B6 Table

1237

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) |



1239 List. B.8 shows the corresponding \LaTeX code.

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

```

1240 1 \begin{center}
1241 2 {\scriptsize
1242 3 \begin{tabularx}{\textwidth}{p{0.1\textwidth}|p{0.2\textwidth}|p{0.5\textwidth}}
1243 4 \caption{Feasible triples for highly variable grid} \label{tab:triple_
1244 5 grid} \\
1245 6 \hline
1246 7 \textbf{Time (s)} &
1247 8 \textbf{Triple chosen} &
1248 9 \textbf{Other feasible triples} \\
1249 10 \hline
1250 11 \endfirsthead
1251 12 \multicolumn{3}{c}{\textit{Continued from previous page}} \\
1252 13 \hline
1253 14 \hline
1254 15 \textbf{Time (s)} &
1255 16 \textbf{Triple chosen} &
1256 17 \textbf{Other feasible triples} \\
1257 18 \hline
1258 19 \endhead
1259 20 \hline
1260 21 \multicolumn{3}{r}{\textit{Continued on next page}} \\
1261 22 \endfoot
1262 23 \hline
1263 24 \endlastfoot
1264 25 \hline
1265 26
1266 27
1267 28 0 & (1, 11, 13725) & (1, 12, 10980), (1, 13, 8235), (2, 2, 0), (3, 1, 0) \\
1268 29 & & \\
1269 30 2745 & (1, 12, 10980) & (1, 13, 8235), (2, 2, 0), (2, 3, 0), (3, 1, 0) \\
1270 31 & & \\
1271 32 5490 & (1, 12, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1272 33 8235 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1273 34 10980 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1274 35 13725 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1275 36 16470 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1276 37 19215 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1277 38 21960 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1278 39 24705 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1279 40 27450 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1280 41 30195 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
1281 42 32940 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1282 43 35685 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1283 44 38430 & (1, 13, 10980) & (2, 2, 2745), (2, 3, 0), (3, 1, 0)

```



```

1294 43 41175 & (1, 12, 13725) & (1, 13, 10980), (2, 2, 2745), (2, 3, 0), (3, 1,
1295      0) \\
1296 44 43920 & (1, 13, 10980) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1297 45 46665 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
1298 46 49410 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
1299 47 52155 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1,
1300      0) \\
1301 48 54900 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1302 49 57645 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1303 50 60390 & (1, 12, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1304 51 63135 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1305 52 65880 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1306 53 68625 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
1307 54 71370 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1308 55 74115 & (1, 12, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1309 56 76860 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1310 57 79605 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1311 58 82350 & (1, 12, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1312 59 85095 & (1, 12, 13725) & (1, 13, 10980), (2, 2, 2745), (2, 3, 0), (3, 1,
1313      0) \\
1314 60 87840 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1315 61 90585 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1316 62 93330 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1317 63 96075 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1318 64 98820 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1319 65 101565 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1320 66 104310 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1321 67 107055 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1322 68 109800 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1323 69 112545 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3,
1324      1, 0) \\
1325 70 115290 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1326 71 118035 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1327 72 120780 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1328 73 123525 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1329 74 126270 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3,
1330      1, 0) \\
1331 75 129015 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
1332 76 131760 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
1333 77 134505 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1334 78 137250 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1335 79 139995 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
1336 80 142740 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
1337 81 145485 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3,
1338      1, 0) \\
1339 82 148230 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
1340 83 150975 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1341 84 153720 & (1, 12, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1342 85 156465 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1343 86 159210 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1344 87 161955 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1345 88 164700 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1346 89 \end{tabularx}
1347 90 }
1348 91 \end{center}

```



1350

B7 Algorithm or Pseudocode Listing

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1352

1353

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

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

Ensure: $y = x^n$

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

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

```

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

```




1354

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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 */

```



1357

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.
```



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 \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 \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 ⁽¹⁾ | 468 | 780 | 780 | 780 | 650 | 650 | 1,404 |
| Maximum HR I/Os ⁽²⁾ | 52 | 52 | 52 | 104 | 52 | 52 | 52 |
| DSP Slices | 600 | 672 | 768 | 1,200 | 1,560 | 1,800 | 2,880 |
| System Monitor | 1 | 1 | 1 | 2 | 3 | 3 | 3 |
| PCIe Gen3 x8 | 2 | 4 | 4 | 4 | 5 | 6 | 6 |
| 150G Interlaken | 3 | 6 | 6 | 6 | 8 | 9 | 0 |
| 100G Ethernet | 3 | 4 | 4 | 6 | 9 | 9 | 3 |
| GTH 16.3Gb/s Transceivers | 20 | 32 | 32 | 40 | 52 | 60 | 48 |
| GTY 30.5Gb/s Transceivers | 20 | 32 | 32 | 40 | 52 | 60 | 0 |

Notes:

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



Virtex UltraScale Device-Package Combinations and Maximum I/Os

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

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

Notes:

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



Virtex UltraScale+ FPGA Feature Summary

Table 8: Virtex UltraScale+ FPGA Feature Summary

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

Notes:

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

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

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

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

Notes:

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

1422

Others

1423

1. ...

1424

2. ...

1425

Award

1426

1. ...

1427

2. ...



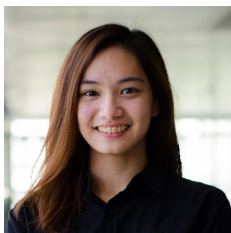
Appendix D VITA



Zion Eric O. Chan is currently taking up his B.Sc. Computer Engineering studies and is in his 3rd academic year. He has made various projects consisting of software and hardware and the combination of both such as a line following robot and a sensor robot during his stay in the university. He is interested in the software side of the Computer Engineering program rather than the hardware side.



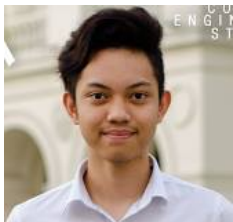
Glenn Rommel P. Comendador is currently taking up his B.Sc. Computer Engineering studies and is in his 3rd academic year. He has also completed several projects such as the Batbot, the FM Radio, and the Line Following Robot. He is currently studying Data Communications, Digital Systems Design, Computer Systems Architecture and Microprocessor Systems in De La Salle University.



Laureen Audrey R. Garcia is currently taking up her B.Sc. Computer Engineering studies and is in her 3rd academic year. She has completed various software and hardware related courses such as Switching Devices, Signal Processing, Advanced Electronics, and Principles of Communication. Her interest in engineering is more inclined to the study of Embedded and Real-Time Systems and Computer Hardware Architecture.



De La Salle University



1445 Mac Excel S. Fallar is currently taking up his B.Sc. Computer
 1446 Engineering studies and is in his 3rd academic year. He has completed multiple projects,
 1447 mostly hardware and software offered in his course, during his stay in the University. He is
 1448 proficient in Programming with the languages, C, C++, and Java. Created a cloud database
 1449 application for android mobile phones called Tap President, and helped create A line
 1450 following robot, and a sensor robot.



1451 Jose Mari Luis L. Lerit is currently taking up his B.Sc. Computer
 1452 Engineering studies at the De la Salle University Manila and is now a 3rd year student. He
 1453 has developed different skills and acquired knowledge in the field of computer engineering.
 1454 He already completed some of his software and hardware courses which enabled him to
 1455 create an android application, a line following mobot and a distance sensor mobot. His
 1456 research interests focuses more on the hardware side, embedded system, microcontroller,
 1457 microprocessor and computer system architecture.



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