Mobile Phone Application for Measuring Air Parameters in Getting Discomfort Index and Amount of Air Pollutants with the Use of a Microcontroller-based System

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

—————————

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

—————————

by

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June, 2016

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ORAL DEFENSE RECOMMENDATION SHEET

This thesis, entitled **Mobile Phone Application for Measuring Air Parameters in Getting Discomfort Index and Amount of Air Pollutants with the Use of a Microcontroller-based System** , prepared and submitted by thesis group, ESG-04, 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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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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ACKNOWLEDGMENT

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

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

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

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ABBREVIATIONS

NOTATION

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

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192   **GLOSSARY**

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LISTINGS

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Chapter 1

INTRODUCTION

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1.1 Background of the Study

There has been many reasons why one tries to avoid any outdoor activity but one of these is how the air feels whether it is too hot or too polluted or even both. One undeniable fact is that heat and humidity all play roles in making the weather hot. Both of these weather parameters are involved in the calculation of the heat index and the discomfort index.

Heat index and discomfort index have their similarities because the factors that affect these two are the temperature and the relative humidity. The heat index is the perceived temperature by people when the rising temperature and the relative humidity is combined. The unit used here is a unit of temperature and the mathematical formula for computing the heat index shows a rather direct square proportionality with the temperature and the humidity. But when it comes to a more human readable scale, reaching 34 degrees Celsius is already a discomfort to some. Reaching at least 46 degrees Celsius is already dangerous to all as this can cause heat stroke and even imminent death to some people. The discomfort index is similar to the heat index but instead, its mathematical formula only indicates a direct proportionality with the temperature and the relative humidity. The scaling is rather similar to that in the heat index. When the discomfort index reaches at least 21 degrees Celsius, it is already a discomfort for some people. Reaching 29 degrees Celsius is already dangerous to all that when it even gets higher, a state of emergency can be declared.

The human body is capable of regulating body temperature because of its abilities as a warm-blooded organism. When the human body detects extreme temperatures, it drastically adjusts the body just to get the internal temperature back to a normal 37 degrees Celsius. When your body detects a lot of heat, it tries to cool itself down by increasing your heart rate and sweating. However, one can sweat too much, he feels drained by the lack of fluids

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in his body causing discomfort, weakness, loss of stamina, and even muscle pains, leading to a heat stroke.

Other than high temperatures and humidity, the pollutants in the air can be harmful to the respiratory system. Dust is a particle suspended in the air and it usually comes from the soil or the pollution. This can cause irritation in the respiratory system because dust entering the lungs can cause serious complications. This is already bad for those with respiratory problems such as asthma or emphysema. Carbon monoxide, however, is a colorless and odorless gas and it usually comes from smoke. When this is inhaled, it can cause serious complications in the body since this inhibits the delivery of oxygen from the blood to the other organs in the body which can cause death. Not only do all of this increase the risk of getting sickness but these also affect the visibility of an area.

This study will focus on a mobile application that enables people to have a foresight on how the outside air feels like. A microcontroller-based system will be used in detecting the parameters stated above while the mobile application will take note of the visibility with the use of the phone's camera.

1.2 Prior Studies

Some of the studies that the group has found are about the temperature and humidity monitoring systems. The temperature system can be constructed by using a simple microcontroller-based system with an important tool, the LM35 where the output voltage is directly proportional to the temperature detected. The same procedure can be done with the humidity sensor but this time, it does not make use of the LM35. Both of these sensors are good for agricultural applications and getting the air quality. Another study involves

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the use of PM10 sensors in order to detect particulate matter that is 10 micrometers wide. An algorithm has been made with the use of the atmospheric reflectance for temporal monitoring. Another study introduces another concept of air monitoring by taking note of the pollutants present which are namely carbon monoxide, PM 2.5 , and ozone which make use of the MQ-7 4 sensor, MQ-131 sensor, and Sharp dust sensor respectively. Another study made use of getting the discomfort index by using temperature, humidity, atmospheric pressure, and carbon dioxide sensors. Finally, a study states the standards set by different parts of the world when it comes to the air quality. These standards all make use of the amount of pollutants present in the air as basis of air quality.

1.3   Problem Statement

Though there have been mobile applications that display the weather in real time, none have been able to show the discomfort index given the data. Also, there are no applications that tell the amount of dust or carbon monoxide in the air considering that these are some important factors when people choose to commute by an ordinary jeepney or do any outdoor activity in urban areas.

The aim of this study is to develop a new mobile application that is able to report the condition of the air such as weather parameters and the amount of pollutants present. The system will make use of a microcontroller along with different sensors that will measure the said parameters. Also, the mobile application will make use of computer vision to measure the visibility in an area.

Can a mobile application be developed to report real time conditions of the air and the amount of pollutants present with the used of a sensor-based microcontroller system?

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1.4 Objectives

1.4.1 General Objective(s)

To design and develop an indoor/outdoor system for getting the discomfort index of the air...;

1.4.2 Specific Objectives

1. To make use of the temperature, humidity, amount of dust, amount of carbon monoxide, and visibility in calculating discomfort index and measuring pollutants...;

2. To utilize different sensors for temperature, humidity, dust, and carbon monoxide measurement...;

3. To make use of computer vision with the use of a cellphone camera to measure visibility ...;

4. To achieve a social impact on the conditions and quality of the air for the people in urban areas where smoke is present and abundant ...;

1.5 Significance of the Study

The significance of this topic is to be able to design and produce a device of checking the air quality and discomfort index for the public health awareness. There are millions of commuters in the Philippines riding jeepneys or light rail transit system. The problem of this way of commuting is the air because there are a lot of old vehicles producing smoke and most people just breathe in either direct or indirect way. It is very important for the people

to know the status of the air to secure their respiratory health. Together with this, the group aim to the user friendly device that anyone can easily understand how to use the device through an android application. Since a lot of people uses android mobile phones, making an application for free will be very helpful. The application will display the required data in graphics so that it is easy to understand for the public and to make the aware of the effect of the environment to their health. This study will surely help a lot of people who still dont know about why it is important to know the air we are breathing outside.

1.6   Assumptions, Scope and Delimitations

1. The given data will only be determined by the air quality index and the discomfort index.

2. The application will be used only for displaying the data gathered in the device.

3. People should be able to know the importance of their respiratory system in the body.

4. Users must aware the connection between air pollution and lung cancer.

5. The device will only deal with the common factors for discomfort such as temperature, humidity, and the amount of dust in the air.

1.7   Description and Methodology

A device for checking air quality and discomfort index can be functional through the use of the electronic sensors attached in the circuit and sensors for dust, humidity, and temperature will provide the data for air quality index and discomfort index. The device will be user

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friendly so that anyone can easily control and use it for the given purpose.The goal for this project is to come up with a device and android application for air quality and discomfort index which will provide data related to the health of the public. Challenges to this project would be the design of the circuit with indicated sensors and the accuracy of the data gathered by the device. The size of the device matters because it has to be user friendly and this will be designed for the typical citizens like commuters. The prototype test would determine if it has accurate data and user friendly in general. Android application will be supporting the device as a method of health awareness. the application will be able to show the data gathered in the device and show the effect of air quality index and discomfort index for respiratory health. The information is also one of the important part because people must know why it is important to know the air quality and their discomfort level.

1.8   Overview

In the first chapter, it will be helpful for readers to understand what is the purpose of making the device and android application and why it is important for the society. It also shows how the project will be implemented in the real world from the hypothesis. For the second part of the paper, there will be a lot of helpful literature related to the air quality, discomfort index, respiratory health, prevention of lung cancer, effect of dust to the human body, circuit design for humidity, dust, and temperature sensors. These literature will guide the group what is the right way to develop a project and make it functional in order to fulfill the standard of the public. Theoretical considerations will be the key part to determine the data gathered from the device because there are theoretical standards in other research to know what are the air quality and discomfort index. Considering the design, it will be

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353 fully electronic design because the implementation in the hardware will be using electronic

354 circuits. methodology will introduce how the data is gathered in the device and represented

355 to the users. result and discussion will be providing the user feedback and the actual data

356 given by the device in real situation. The value of this project will be determined in the

357 conclusion based on all the provided data and actual simulation. It is the most important

358 part to prove how this project fulfilled its purpose for the public health awareness.

Chapter 2

LITERATURE REVIEW

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There are several existing studies or researches about different kinds of applications of air parameters. Most of the studies found relating to these parameters are temperature, humidity, temporal, wireless air quality and discomfort index monitoring systems and air quality standards.

2.1   Temperature Monitoring System

An important parameter, not only in the air but also in everything, is the temperature. It is very important to monitor temperature of objects because most objects are sensitive to changes in the temperature such as products and some machines. Some existing researches of temperature monitoring system are found in the field of agriculture. Recent studies [Chavan and V.Karande, 2014] shows how important data-acquisition systems in the agriculture through environmental monitoring. Environmental monitoring refers to the gathering of data of some parameters in the environment that may affect the products. Automated measurements are beneficial because gathering of data and measurements are made several times. Chavan and Karande have developed a system for wireless monitoring of soil moisture, temperature and humidity in the field of agriculture. The system uses a temperature sensor, humidity sensor and soil moisture sensor that are connected to an AVR microcontroller. It also uses GSM-Zigbee based remote monitoring and control system. The application of Zigbee to the monitoring system in the agriculture reduces human power and enables to evaluate some accurate changes that will happen.

Aside from the agricultural implementation of temperature monitoring, there are also existing studies that involves its application to automated systems for electronic devices or appliances. [Mohamed Abd El-Latif Mowad, 2014] designed a smart home automated

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control system. The system uses a microcontroller for sensors and android application for the transmission of data and the receiving of data. One of the four major fields of the smart home system or SHS is the environmental monitoring, which includes the monitoring of the humidity and the temperature. The main components used in the system are microcontroller, adruino board, android and a bluetooth module. Wireless internet services are also used for several monitoring and controlling processes. The passive infrared sensors are capable off detecing movements of a human being through sensing the changes in the temperature over the scene. The SHS also uses LM35 temperature sensor for the Temperature sensing system for Air Conditioner. The system can transfer data from the sensors to the android phone. On the same way, it can transmit data or commands from the android to the appliances. The wireless monitoring of temperature allows the user to control electronic devices or appliances from anywhere in the world.

2.2   Humidity Monitoring System

Humidity is always associated with temperature. It plays an important role to human due to the skin being sensitive to the changes in humidity. This is also the reason why humans sweat. Not only humans are affected by the changes in the humidity in the air but also applies to the things related to the field of agriculture.

A group of researchers [Aji Hanggoro and Sari, 2013] designed a green house monitoring and controlling system using an android mobile application. The system can control the humidity inside a green house, based on the readings of the humidity sensor through the microcontroller which is connected to the central server and can be accessed through Wi-Fi connection. The system is consists of humidity sensor, Arduino UNO microcontroller,

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414 serial communication, wireless connection and a computer. The data from the sensor

415 will be transmitted to the microcontroller and transferred to the computer through serial

416 communication. The computer will transmit the data to the android phone via wireless

417 connection and the android phone can now control the system depending on the commands

418 that will be selected. The android can receive data from the humidity sensor, send data

419 for water sprayer to turn on, send data for stepper motor to work and other commands

420 that the system is capable of doing. This system ensures the condition of the green house

421 environment to be in good condition.

422 Other than agricultural applications, studies also shows how air quality such as tem-

423 perature and humidity affects the health of a human being. Indoor air quality or IAQ is

424 an important factor that may affect the level of comfort and the health of the people. This

425 may increase the discomfort index of a human being which may result to difficulties in con-

426 centration or even headaches. [Folea and Mois, 2015] develop a wireless battery-powered

427 system for online ambient monitoring. The system has the ability to monitor temperature,

428 humidity, carbon dioxide level, absolute pressure and intensity of light in the indoor spaces.

429 The data gathered can be sent through a computer for visualization and can send SMS for

430 alarms. The system has sensors such as ambient, temperature, humidity and many more

431 sensors to evaluate the indoor air quality. Wi-Fi connection is used as a data transmission,

432 from the sensors to the computer, due to the fact that Wi-Fi can be found in almost every

433 home. The study of indoor air quality will help prevent or solve issues that may affect the

434 health and the performance of the people.

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2.3 PM$_{10}$ Temporal Monitoring

PM$_{10}$ or particulate matter that have a diameter of 10 micrometers wide which are classified under fine particles. One study [Wong et al., 2007] used an internet protocol camera to observe real time changes in the amount of particles found in the air. The camera points to a reference location and the still images were divided into the RGB bands.

They developed an algorithm which makes use of the atmospheric reflectance and the concentration of the PM$_{10}$ using regression. The amount of reflectance is measured using a spectroradiometer and the concentration of the particles are determined by the different RGB bands of the camera. The PM$_{10}$ and the atmospheric reflectance are found to be linearly related through using the skylight parameter model, which utilizes the sun's radiation. The results produced were compared to a DustTrak meter and provide a high correlation coefficient of .78.

2.4 Wireless Air Quality Monitoring System

A study [Reilly et al., 2015] monitored the amount of different air pollutants using Arduino. The pollutants that are measured are carbon monoxide, PM$_{2.5}$, and ozone which make use of the MQ-7 sensor, MQ-131 sensor, and Sharp dust sensor respectively. The sensors are mounted onto a redboard as well as GSM shield to send data wirelessly. The sensors are calibrated using a co-located ADEQ (Air Quality Division) sensor and were validated. The device is placed around the metro area and the data collected will be compared to a monitoring station. Data was collected for a period of time and a trend was found in CO and ozone levels. However, the use of the Sharp dust sensor was not very effective but could find slight differences at high pollution times with low pollution times.

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457 Another similar study [Hebbar et al., 2014] of an air monitoring device is implemented

458 using a microcontroller where several sensors are placed and data is sent through GSM

459 wirelessly. The design tests the amount of CO_2 levels indoors. It also measures the

460 temperature and humidity of the atmosphere locally. Calibration of the sensors is done by

461 concentrating known amount of a certain gas into a test chamber and determine its offset

462 from the results obtained. The design was tested in a seminar hall and the results obtained

463 showed that the start and end of each class attributed to the increase in CO_2 emission. The

464 design also shows the data through an online GUI.

465 One similar design, called HazeWatch, is done using several sensors and cloud com-

466 puting [Hu et al., 2016]. The design is made compact and portable and can be mounted

467 onto a car or bike. Data is harvested using a mobile phone and records the location in

468 real time. Data is then sent wirelessly to cloud-based servers and is interpolated (Inverse

469 Weighing and Ordinary Kriging interpolation) to generate estimates. The data can then be

470 view visually using contour maps of the pollution or gas concentration levels in the area.

471 The results obtained are compared to similar products (*Node* and *SensorDrone*)

2.5 Discomfort Index Monitoring System

473 A research was made about the importance of monitoring and controlling of atmospheric

474 conditions to the efficiency of the performance of the human beings [Noh et al., 2013]

475 . They designed a wireless sensor module that uses a Zigbee communication and sensor

476 module, which consists of temperature, humidity, CO_2 and atmospheric pressure sensor,

477 that maintains a comfortable environment for human beings or to prevent discomfort.

478 The sensor module is the transmitter which delivers the sensor data to the receiver and

479   the receiver will transmit the filtered or recovered sensor data to a microcontroller board

480   in monitoring the room environment. The room monitoring system is able to provide a

481   comfortable environment for human beings through the wireless sensor network or WSN

482   for monitoring the room environment.

2.6   Air Quality Standards

484   This review shows the different indoor air quality standards set by different countries across

485   the world. The data is collected from documents from different health and environmental

486   organization. This paper can be set as a tool for evaluating acceptable concentrations of

487   different pollutants within an area. The pollutants included in this study are "carbon dioxide

488   (CO_2), carbon monoxide (CO), formaldehyde (HCHO), nitrogen dioxide (NO_2), sulfur

489   dioxide (SO_2), total volatile organic compounds (TVOCs) and particulate matter ($PM_{2.5}$

490   and PM_{10})." The amount allowable depends on how bad the amount of a certain pollutant

491   exists indoors. The paper also explains different harmful health effects each pollutant has

492   on the human body.

Chapter 3

THEORETICAL CONSIDERATIONS

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3.1   Summary

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Fig. 3.1   A quadrilateral image example.

Chapter 4

DESIGN CONSIDERATIONS

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4.1 Summary

597 **Chapter 5**

598 **METHODOLOGY**

Contents

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5.1   Implementation

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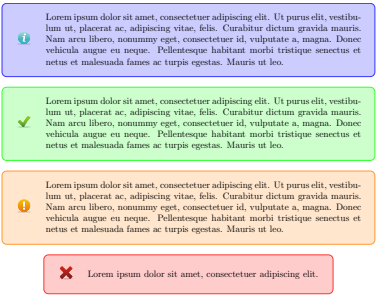Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Etiam lobortis facilisis sem. Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus placerat pede. Vivamus nunc nunc, molestie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

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5.2   Evaluation

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5.3 Summary

Chapter 6

RESULTS AND DISCUSSION

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6.1 Summary

Chapter 7

CONCLUSIONS, RECOMMENDATIONS, 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 Thesisare listed as follows.

- the ;

- the ;

- the ;

7.3 Recommendations

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7.4   Future Prospects

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

1. the . . . .

2. the . . . .

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Appendix A
ANSWERS TO QUESTIONS TO THIS THESIS

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A1   How important is the problem to practice?

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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1045 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.
1046 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit
1047 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

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

1050 Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Etiam lobortis facilisis sem.
1051 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec
1052 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus
1053 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.
1054 Praesent in sapien. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Duis fringilla
1055 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue
1056 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.
1057 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit
1058 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

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

1061 Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Etiam lobortis facilisis sem.
1062 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec
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1065 Praesent in sapien. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Duis fringilla
1066 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue
1067 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.
1068 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit
1069 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

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

1072 Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Etiam lobortis facilisis sem.
1073 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec
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Praesent in sapien. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Duis fringilla tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris. Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit amet ipsum. Nunc quis urna dictum turpis accumsan semper.

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

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

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

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A8.1 What are the weaknesses of your proposal?

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

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1108 Praesent in sapien. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Duis fringilla
1109 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue
1110 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.
1111 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit
1112 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

1113 **Appendix B**
1114 **USAGE EXAMPLES**

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1115   The user is expected to have a working knowledge of LaTeX. A good introduction
1116   is in [Oetiker et al., 2014]. Its latest version can be accessed at http://www.ctan.org/
1117   tex-archive/info/lshort.

B1   Equations

1119   The following examples show how to typeset equations in LaTeX. This section also shows
1120   examples of the use of `\gls{ }` commands in conjunction with the items that are in
1121   the `notation.tex` file. **Please make sure that the entries in `notation.tex` are**
1122   **those that are referenced in the LaTeX document files used by this Thesis. Please**
1123   **comment out unused notations and be careful with the commas and brackets in**
1124   `notation.tex` .
1125   In (B.1), the output signal $y\left(t\right)$ is the result of the convolution of the input signal $x\left(t\right)$
1126   and the impulse response $h\left(t\right)$.

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

1127   Other example equations are as follows.

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

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

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

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1128   The verbatim LaTeX code of Sec. B1 is in List. B.1.

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

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

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B2 Notations

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

Math alphabets

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

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

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

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

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

Vector symbols

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

Matrix symbols

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

---

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

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Tensor symbols

1143

Symbols for tensors are sans-serif bold italic,

1144

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

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

1145

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

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1146 **Bold math version**

1147 The "bold" math version is selected with the commands \boldmath or \mathversion{bold}

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

mathit $A, B, \Gamma, \Delta, \Theta, \Lambda, \Xi, \Pi, \Sigma, \Phi, \Psi, \Omega, \text{ff}, \text{fi}, ß, \,°\,, !, v, w, 0, 1, 9$

mathrm $A, B, \Gamma, \Delta, \Theta, \Lambda, \Xi, \Pi, \Sigma, \Phi, \Psi, \Omega, \text{ff}, \text{fi}, ß, \,°\,, !, v, w, 0, 1, 9$

mathbf $A, B, \Gamma, \Delta, \Theta, \Lambda, \Xi, \Pi, \Sigma, \Phi, \Psi, \Omega, \text{ff}, \text{fi}, ß, \,°\,, !, v, w, 0, 1, 9$

mathsf   A, B, Γ, Δ, Θ, Λ, Ξ, Π, Σ, Φ, Ψ, Ω, ff, fi, ß, ˚, !, v, w, 0, 1, 9

mathtt   A, B, Γ, Δ, Θ, Λ, Ξ, Π, Σ, Φ, Ψ, Ω, ↑, ↓, ß, ˚, !, v, w, 0, 1, 9

1148 New alphabets bold-italic, sans-serif-italic, and sans-serif-bold-italic.

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

mathsfit   A, B, Γ, Δ, Θ, Λ, Ξ, Π, Σ, Φ, Ψ, Ω, α, β, π, ν, ω, v, w, 0, 1, 9

mathsfbfit   A, B, Γ, Δ, Θ, Λ, Ξ, Π, Σ, Φ, Ψ, Ω, α, β, π, ν, ω, v, w, 0, 1, 9

1149 Do the math alphabets match?

1150 $ax\alpha\omega ax\alpha\omega ax\alpha\omega$ TCΘΓTCΘΓTCΘΓ

Vector symbols

1151

1152 Alphabetic symbols for vectors are boldface italic, $\boldsymbol{\lambda} = \boldsymbol{e_1} \cdot \boldsymbol{a}$, while numeric ones (e.g.

1153 the zero vector) are bold upright, $\boldsymbol{a} + \mathbf{0} = \boldsymbol{a}$.

Matrix symbols

1154

1155 Symbols for matrices are boldface italic, too:[2] $\boldsymbol{\Lambda} = \boldsymbol{E} \cdot \boldsymbol{A}.$

Tensor symbols

1156

1157 Symbols for tensors are sans-serif bold italic,

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

1158 The permittivity tensor describes the coupling of electric field and displacement:

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

1159

---

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

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1160   The verbatim LaTeX code of Sec. B2 is in List. B.2.

Listing B.2: Sample LaTeX code for notations usage

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

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```
1215   53   Alphabetic symbols for vectors are boldface italic,
1216   54   $\vec{\lambda}=\vec{e}_{1}\cdot\vec{a}$,
1217   55   while numeric ones (e.g. the zero vector) are bold upright,
1218   56   $\vec{a} + \vec{0} = \vec{a}$.
1219   57
1220   58   \subsection*{Matrix symbols}
1221   59
1222   60   Symbols for matrices are boldface italic, too:%
1223   61   \footnote{However, matrix symbols are usually capital letters whereas
1224        vectors
1225   62   are small ones. Exceptions are physical quantities like the force
1226   63   vector $\vec{F}$ or the electrical field $\vec{E}$.%
1227   64   }
1228   65   $\matrixsym{\Lambda}=\matrixsym{E}\cdot\matrixsym{A}.$
1229   66
1230   67
1231   68   \subsection*{Tensor symbols}
1232   69
1233   70   Symbols for tensors are sans-serif bold italic,
1234   71
1235   72   \[
1236   73       \tensorsym{\alpha}  =  \tensorsym{e}\cdot\tensorsym{a}
1237   74       \quad \Longleftrightarrow \quad
1238   75       \alpha_{ijl}  =  e_{ijk}\cdot a_{kl}.
1239   76   \]
1240   77
1241   78
1242   79   The permittivity tensor describes the coupling of electric field and
1243   80   displacement: \[
1244   81   \vec{D}=\epsilon_{0}\tensorsym{\epsilon}_{\mathrm{r}}\vec{E}\]
1245   82
1246   83
1247   84
1248   85   \newpage
1249   86   \subsection*{Bold math version}
1250   87
1251   88   The ``bold'' math version is selected with the commands
1252   89   \verb+\boldmath+ or \verb+\mathversion{bold}+
1253   90
1254   91   {\boldmath
1255   92       \begin{eqnarray*}
1256   93       \mbox{mathnormal} &  & \teststring \\
1257   94       \mbox{mathit} &  & \mathit{\teststring}\\
1258   95       \mbox{mathrm} &  & \mathrm{\teststring}\\
1259   96       \mbox{mathbf} &  & \mathbf{\teststring}\\
1260   97       \mbox{mathsf} &  & \mathsf{\teststring}\\
1261   98       \mbox{mathtt} &  & \mathtt{\teststring}
1262   99       \end{eqnarray*}
1263   100       New alphabets bold-italic, sans-serif-italic, and sans-serif-bold-
1264              italic.
1265   101       \begin{eqnarray*}
1266   102       \mbox{mathbfit}     &  & \mathbfit{\teststring}\\
1267   103       \mbox{mathsfit}     &  & \mathsfit{\teststring}\\
1268   104       \mbox{mathsfbfit} &  & \mathsfbfit{\teststring}
1269   105       \end{eqnarray*}
1270   106       %
1271   107       Do the math alphabets match?
```

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```
1272   108
1273   109       $
1274   110       \mathnormal   {a x \alpha \omega}
1275   111       \mathbfit     {a x \alpha \omega}
1276   112       \mathsfbfit{a x \alpha \omega}
1277   113       \quad
1278   114       \mathsfbfit{T C \Theta \Gamma}
1279   115       \mathbfit     {T C \Theta \Gamma}
1280   116       \mathnormal   {T C \Theta \Gamma}
1281   117       $
1282   118
1283   119       \subsection*{Vector symbols}
1284   120
1285   121       Alphabetic symbols for vectors are boldface italic,
1286   122       $\vec{\lambda}=\vec{e}_{1}\cdot\vec{a}$,
1287   123       while numeric ones (e.g. the zero vector) are bold upright,
1288   124       $\vec{a} + \vec{0} = \vec{a}$.
1289   125
1290   126
1291   127
1292   128
1293   129       \subsection*{Matrix symbols}
1294   130
1295   131       Symbols for matrices are boldface italic, too:%
1296   132       \footnote{However, matrix symbols are usually capital letters whereas
1297              vectors
1298   133       are small ones. Exceptions are physical quantities like the force
1299   134       vector $\vec{F}$ or the electrical field $\vec{E}$.%
1300   135       }
1301   136       $\matrixsym{\Lambda}=\matrixsym{E}\cdot\matrixsym{A}.$
1302   137
1303   138
1304   139       \subsection*{Tensor symbols}
1305   140
1306   141       Symbols for tensors are sans-serif bold italic,
1307   142
1308   143       \[
1309   144           \tensorsym{\alpha}  =  \tensorsym{e}\cdot\tensorsym{a}
1310   145           \quad \Longleftrightarrow \quad
1311   146           \alpha_{ijl}  =  e_{ijk}\cdot a_{kl}.
1312   147       \]
1313   148
1314   149       The permittivity tensor describes the coupling of electric field and
1315   150       displacement: \[
1316   151       \vec{D}=\epsilon_{0}\tensorsym{\epsilon}_{\mathrm{r}}\vec{E}\]
1317   152   }
1318
```

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B3 Abbreviation

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

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

- extensible markup language (xml) and cascading style sheet (css).

- Next use: xml and css.

- Full form: extensible markup language (xml) and cascading style sheet (css).

- Reset again.

- Start with a capital. Hyper-text markup language (html).

- Next: Html. Full: Hyper-text markup language (html).

- Prefer capitals? Extensible markup language (XML). Next: XML. Full: extensible markup language (XML).

- Prefer small-caps? Cascading style sheet (CSS). Next: CSS. Full: cascading style sheet (CSS).

- Resetting all acronyms.

- Here are the acronyms again:

- Hyper-text markup language (HTML), extensible markup language (XML) and cascading style sheet (CSS).

- Next use: HTML, XML and CSS.

- Full form: Hyper-text markup language (HTML), extensible markup language (XML) and cascading style sheet (CSS).

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1348   • Provide your own link text: style sheet.

1349   The verbatim LaTeX code of Sec. B3 is in List. B.3.

Listing B.3: Sample LaTeX code for abbreviations usage

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

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B4 Glossary

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

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

- Matrices are usually denoted by a bold capital letter, such as A. The matrix's (i, j)th element is usually denoted a_{ij}. Matrix $\mathbf{I}$ is the identity matrix.

- A set, denoted as $\mathcal{S}$, is a collection of objects.

- The universal set, denoted as $\mathcal{U}$, is the set of everything.

- The empty set, denoted as $\emptyset$, contains no elements.

- The cardinality of a set, denoted as $|\mathcal{S}|$, is the number of elements in the set.

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

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

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

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B5 Figure

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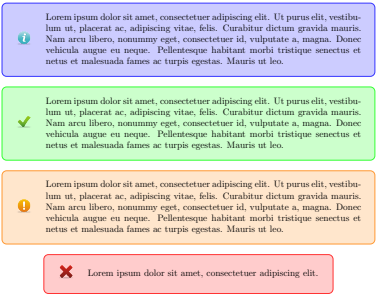
Fig. B.1   A quadrilateral image example.

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1367   Fig. B.1 is a gray box enclosed by a dark border. List. B.5 shows the corresponding
1368   LaTeX code.

Listing B.5: Sample LaTeX code for a single figure

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

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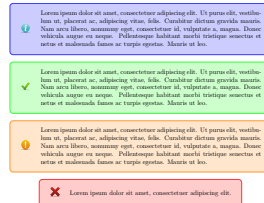
(a) A sub-figure in the top row.
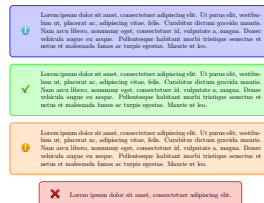
(b) A sub-figure in the middle row.

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

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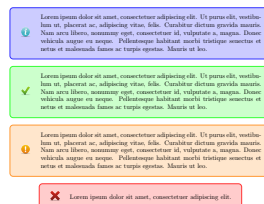
Listing B.6: Sample LaTeX code for three figures on top of each other

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

De La Salle University
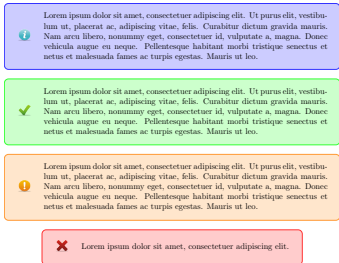
(a) A sub-figure in the upper-left corner.

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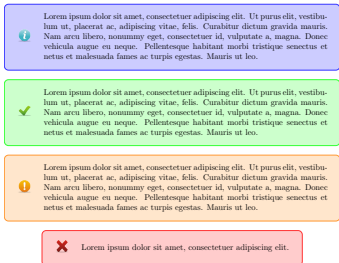
(c) A sub-figure in the lower-left corner.

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

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

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Listing B.7: Sample LaTeX code for the four figures

```latex
\begin{figure}[!htbp]
\centering
\subbottom[A sub-figure in the upper-left corner.]{
\includegraphics[width=0.45\textwidth]{example}
\label{fig:upprleft}
}
\hfill
\subbottom[A sub-figure in the upper-right corner.]{
\includegraphics[width=0.45\textwidth]{example}
\label{fig:uppright}
}
\vfill
\subbottom[A sub-figure in the lower-left corner.]{
\includegraphics[width=0.45\textwidth]{example}
\label{fig:lowerleft}
}
\hfill
\subbottom[A sub-figure in the lower-right corner]{
\includegraphics[width=0.45\textwidth]{example}
\label{fig:lowright}
}
\caption{Four figures in each corner. See List.~\ref{lst:fourfigs} for
    the corresponding \LaTeX \ code.}
\label{fig:fourfig}
\end{figure}
```

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1369 ## B6 Table

1370 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

B. Usage Examples

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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)

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List. B.8 shows the corresponding LaTeX code.

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

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

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```
1427  43  41175 & (1, 12, 13725) & (1, 13, 10980), (2, 2, 2745), (2, 3, 0), (3, 1,
1428           0) \\
1429  44  43920 & (1, 13, 10980) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1430  45  46665 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
1431  46  49410 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
1432  47  52155 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1,
1433           0) \\
1434  48  54900 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1435  49  57645 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1436  50  60390 & (1, 12, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1437  51  63135 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1438  52  65880 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1439  53  68625 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
1440  54  71370 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1441  55  74115 & (1, 12, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1442  56  76860 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1443  57  79605 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1444  58  82350 & (1, 12, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1445  59  85095 & (1, 12, 13725) & (1, 13, 10980), (2, 2, 2745), (2, 3, 0), (3, 1,
1446           0) \\
1447  60  87840 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1448  61  90585 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1449  62  93330 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1450  63  96075 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1451  64  98820 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1452  65  101565 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1453  66  104310 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1454  67  107055 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1455  68  109800 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1456  69  112545 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3,
1457           1, 0) \\
1458  70  115290 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1459  71  118035 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1460  72  120780 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1461  73  123525 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1462  74  126270 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3,
1463           1, 0) \\
1464  75  129015 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
1465  76  131760 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
1466  77  134505 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1467  78  137250 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1468  79  139995 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
1469  80  142740 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
1470  81  145485 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3,
1471           1, 0) \\
1472  82  148230 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
1473  83  150975 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1474  84  153720 & (1, 12, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1475  85  156465 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1476  86  159210 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1477  87  161955 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1478  88  164700 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1479  89  \end{tabularx}
1480  90  }
1481  91  \end{center}
1482
```

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B7   Algorithm or Pseudocode Listing

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

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

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

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

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

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

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B8 Program/Code Listing

1487

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.

1488
1489

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

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

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1490   List. B.11 shows the corresponding LaTeX code.

Listing B.11: Sample LaTeX code for program listing

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

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B9 Referencing

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

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

Listing B.12: Sample LaTeX code for referencing sections

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

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

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B9.1 A subsection

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

Listing B.13: Sample LaTeX code for referencing subsections

```
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.
```

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

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B9.1.1   A sub-subsection

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

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

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

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B10 Index

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

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

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

Listing B.15: Sample LaTeX code for Index usage

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

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

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

Listing B.16: Sample LaTeX code for including PDF pages

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

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XILINX.

UltraScale Architecture and Product Overview

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.

DS890 (v2.1) April 27, 2015   www.xilinx.com
Preliminary Product Specification   8

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Virtex UltraScale Device-Package Combinations and Maximum I/Os

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

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

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

Virtex UltraScale+ FPGA Feature Summary

Table 8: **Virtex UltraScale+ FPGA Feature Summary**

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

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

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

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

Package [1][2][3]	Package Dimensions (mm)	VU3P	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. ...

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Others

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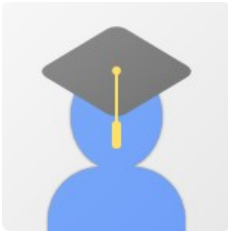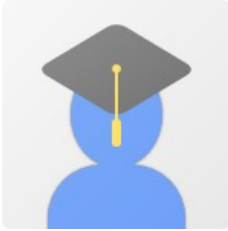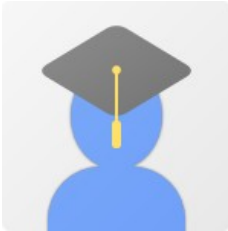## Award

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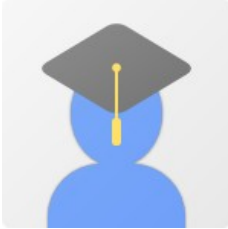1560 2. . . .

Appendix D
VITA

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1577 microcontroller simulation and programming.

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