



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

---

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

---

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

---

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

July, 2016



De La Salle University

## 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:

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

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

---

**Engr. Donabel D. Abuan**  
*Adviser*

July 23, 2016



De La Salle University

## THESIS APPROVAL 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:

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

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.

### PANEL OF EXAMINERS

---

**Engr. Julius P. Bancud**  
*Chair*

---

**Engr. Blanca I. Bucao**  
*Member*

---

**Dr. Rionel B. Caldo**  
*Member*

---

**Engr. Donabel D. Abuan**  
*Adviser*

Date: July 23, 2016



De La Salle University

60  
61  
62  
63

2016

All Rights Reserved. No part of this publication may be reproduced, stored in an information retrieval system, or transmitted, in any form or by any means, electronic, mechanical, by photocopying, scanning, recording, or otherwise, except under the terms of the applicable law.



De La Salle University

64

## ACKNOWLEDGMENT

65

66

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



67

## ABSTRACT

68

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

69

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



70

## TABLE OF CONTENTS

71

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

72

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

73

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

74

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

75

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

76

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

77

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

78

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

79

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

80

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

81

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

82

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

83

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

84

1.2 Prior Studies . . . . .	3
-----------------------------	---

85

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

86

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

87

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

88

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

89

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

90

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

91

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

92

1.8 Estimated Work Schedule and Budget . . . . .	7
--	---

93

1.9 Overview . . . . .	7
------------------------	---

94

Chapter 2 LITERATURE REVIEW	11
-----------------------------	----

95

2.1 Temperature Monitoring System . . . . .	12
---	----



96	2.2 Humidity Monitoring System . . . . .	13
97	2.3 PM <sub>10</sub> Temporal Monitoring . . . . .	15
98	2.4 Wireless Air Quality Monitoring System . . . . .	15
99	2.5 Discomfort Index Monitoring System . . . . .	16
100	2.6 Air Quality Standards . . . . .	17
101	<b>Chapter 3 THEORETICAL CONSIDERATIONS</b>	<b>18</b>
102	3.1 Summary . . . . .	20
103	<b>Chapter 4 DESIGN CONSIDERATIONS</b>	<b>22</b>
104	4.1 Summary . . . . .	24
105	<b>Chapter 5 METHODOLOGY</b>	<b>25</b>
106	5.1 Implementation . . . . .	26
107	5.2 Evaluation . . . . .	28
108	5.3 Summary . . . . .	30
109	<b>Chapter 6 RESULTS AND DISCUSSION</b>	<b>31</b>
110	6.1 Summary . . . . .	33
111	<b>Chapter 7 CONCLUSIONS, RECOMMENDATIONS, AND FUTURE DIREC-</b>	
112	<b>TIVES</b>	<b>34</b>
113	7.1 Concluding Remarks . . . . .	35
114	7.2 Contributions . . . . .	35
115	7.3 Recommendations . . . . .	35
116	7.4 Future Prospects . . . . .	37
117	<b>References</b>	<b>38</b>
118	<b>Appendix A ANSWERS TO QUESTIONS TO THIS THESIS</b>	<b>39</b>
119	A1 How important is the problem to practice? . . . . .	40
120	A2 How will you know if the solution/s that you will achieve would be better	
121	than existing ones? . . . . .	40
122	A2.1 How will you measure the improvement/s? . . . . .	40
123	A2.1.1 What is/are your basis/bases for the improvement/s? . .	41
124	A2.1.2 Why did you choose that/those basis/bases? . . . . .	41
125	A2.1.3 How significant are your measure/s of the improvement/s? .	41
126	A3 What is the difference of the solution/s from existing ones? . . . . .	42
127	A3.1 How is it different from previous and existing ones? . . . . .	42
128	A4 What are the assumptions made (that are behind for your proposed solution	
129	to work)? . . . . .	42





130	A4.1	Will your proposed solution/s be sensitive to these assumptions? .	43
131	A4.2	Can your proposed solution/s be applied to more general cases	
132		when some of the assumptions are eliminated? If so, how? . . . .	43
133	A5	What is the necessity of your approach / proposed solution/s? . . . . .	43
134	A5.1	What will be the limits of applicability of your proposed solution/s?	44
135	A5.2	What will be the message of the proposed solution to technical	
136		people? How about to non-technical managers and business men?	44
137	A6	How will you know if your proposed solution/s is/are correct? . . . . .	44
138	A6.1	Will your results warrant the level of mathematics used (i.e., will	
139		the end justify the means)? . . . . .	45
140	A7	Is/are there an/_ alternative way/s to get to the same solution/s? . . . . .	45
141	A7.1	Can you come up with illustrating examples, or even better, counter	
142		examples to your proposed solution/s? . . . . .	45
143	A7.2	Is there an approximation that can arrive at the essentially the same	
144		proposed solution/s more easily? . . . . .	46
145	A8	If you were the examiner of your proposal, how would you present the	
146		proposal in another way? . . . . .	46
147	A8.1	What are the weaknesses of your proposal? . . . . .	46
148	<b>Appendix B</b>	<b>USAGE EXAMPLES</b>	<b>48</b>
149	B1	Equations . . . . .	49
150	B2	Notations . . . . .	51
151	B3	Abbreviation . . . . .	57
152	B4	Glossary . . . . .	59
153	B5	Figure . . . . .	60
154	B6	Table . . . . .	66
155	B7	Algorithm or Pseudocode Listing . . . . .	70
156	B8	Program/Code Listing . . . . .	72
157	B9	Referencing . . . . .	74
158	B9.1	A subsection . . . . .	75
159	B9.1.1	A sub-subsection . . . . .	76
160	B10	Index . . . . .	77
161	B11	Adding Relevant PDF Pages (e.g. Standards, Datasheets, Specification	
162		Sheets, Application Notes, etc.) . . . . .	78
163	<b>Appendix C</b>	<b>PUBLICATION LIST AND AWARD</b>	<b>82</b>
164	<b>Appendix D</b>	<b>VITA</b>	<b>84</b>
165	<b>Index</b>		<b>86</b>



166

## LIST OF FIGURES

167

3.1 A quadrilateral image example. . . . . 21

168

B.1 A quadrilateral image example. . . . . 60

169

B.2 Figures on top of each other. See List. B.6 for the corresponding  $\text{\LaTeX}$  code. 62

170

B.3 Four figures in each corner. See List. B.7 for the corresponding  $\text{\LaTeX}$  code. . 64



171

## LIST OF TABLES

172	1.1	Gantt Chart Part 1 . . . . .	8
173	1.2	Gantt Chart Part 2 . . . . .	9
174	1.3	Estimated Budget . . . . .	10
175	B.1	Feasible triples for highly variable grid . . . . .	66
176	B.2	Calculation of $y = x^n$ . . . . .	70



177

## ABBREVIATIONS

178	AC	Alternating Current.....	57
179	CSS	Cascading Style Sheet .....	57
180	HTML	Hyper-text Markup Language .....	57
181	XML	eXtensible Markup Language .....	57



## NOTATION

183	$ \mathcal{S} $	the number of elements in the set $\mathcal{S}$ .....	59
184	$\emptyset$	the set with no elements .....	59
185	$h(t)$	impulse response .....	49
186	$\mathcal{S}$	a collection of distinct objects .....	59
187	$\mathcal{U}$	the set containing everything .....	59
188	$x(t)$	input signal represented in the time domain .....	49
189	$y(t)$	output signal represented in the time domain .....	49

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



196

## GLOSSARY

197

matrix a concise and useful way of uniquely representing and working with linear transformations; a rectangular table of elements ..... 59



198

## LISTINGS

199	B.1 Sample $\LaTeX$ code for equations and notations usage . . . . .	50
200	B.2 Sample $\LaTeX$ code for notations usage . . . . .	54
201	B.3 Sample $\LaTeX$ code for abbreviations usage . . . . .	58
202	B.4 Sample $\LaTeX$ code for glossary and notations usage . . . . .	59
203	B.5 Sample $\LaTeX$ code for a single figure . . . . .	61
204	B.6 Sample $\LaTeX$ code for three figures on top of each other . . . . .	63
205	B.7 Sample $\LaTeX$ code for the four figures . . . . .	65
206	B.8 Sample $\LaTeX$ code for making typical table environment . . . . .	68
207	B.9 Sample $\LaTeX$ code for algorithm or pseudocode listing usage . . . . .	71
208	B.10 Computing Fibonacci numbers . . . . .	72
209	B.11 Sample $\LaTeX$ code for program listing . . . . .	73
210	B.12 Sample $\LaTeX$ code for referencing sections . . . . .	74
211	B.13 Sample $\LaTeX$ code for referencing subsections . . . . .	75
212	B.14 Sample $\LaTeX$ code for referencing sub-subsections . . . . .	76
213	B.15 Sample $\LaTeX$ code for Index usage . . . . .	77
214	B.16 Sample $\LaTeX$ code for including PDF pages . . . . .	78



## Chapter 1

### INTRODUCTION

#### Contents

---

1.1	Background of the Study . . . . .	2
1.2	Prior Studies . . . . .	3
1.3	Problem Statement . . . . .	4
1.4	Objectives . . . . .	5
1.4.1	General Objective(s) . . . . .	5
1.4.2	Specific Objectives . . . . .	5
1.5	Significance of the Study . . . . .	5
1.6	Assumptions, Scope and Delimitations . . . . .	6
1.7	Description and Methodology . . . . .	6
1.8	Estimated Work Schedule and Budget . . . . .	7
1.9	Overview . . . . .	7

---





## 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



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

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

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

## 269 1.2 Prior Studies

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



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?



298

## 1.4 Objectives

299

### 1.4.1 General Objective(s)

300

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

301

302

### 1.4.2 Specific Objectives

303

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

304

305

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

306

307

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

308

309

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...;

310

311

## 1.5 Significance of the Study

312

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

313

314

315

316



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

## 324 **1.6 Assumptions, Scope and Delimitations**

- 325 1. The given data will only be determined by the air quality index and the discomfort  
326 index.
- 327 2. The application will be used only for displaying the data gathered in the device.
- 328 3. People should be able to know the importance of their respiratory system in the body.
- 329 4. Users must aware the connection between air pollution and lung cancer.
- 330 5. The device will only deal with the common factors for discomfort such as temperature,  
331 humidity, and the amount of dust in the air.

## 332 **1.7 Description and Methodology**

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



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 Estimated Work Schedule and Budget

## 1.9 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



TABLE 1.1 GANNT CHART PART 1

	W1	W2	W3	W4	W5	W6
Research for a topic	X					
Submission of proposed topic		X				
Background of the study			X			
Statement of the problem			X			
Objectives			X			
Abstract			X			
Scope and delimitation			X			
Review of related literature			X			
Methodology				X	X	
Individual Research				X	X	X
Schematic diagram				X	X	X
Balancing methods						
Sensors						X
Sensors Calibration						
PIC programming						X
Android programming						X
Android layout						
OpenCV Integration						X
Board design						
Board layout						
Fabrication						
Mounting						
Proofreading and Revisions						
Final documentation						
Defense						



TABLE 1.2 GANTT CHART PART 2

	W7	W8	W9	W10	W11	W12	W13	W14
Research for a topic								
Submission of proposed topic								
Background of the study								
Statement of the problem								
Objectives								
Abstract								
Scope and delimitation								
Review of related literature								
Methodology								
Individual Research	X	X	X	X	X	X		
Schematic diagram								
Balancing methods								
Sensors	X	X						
Sensors Calibration			X	X	X	X		
PIC programming	X	X	X	X	X	X		
Android programming	X	X	X	X	X	X		
Android layout				X	X	X		
OpenCV Integration	X	X	X					
Board design								
Board layout								
Fabrication								
Mounting								
Proofreading and Revisions							X	X
Final documentation							X	X
Defense								X





TABLE 1.3 ESTIMATED BUDGET

Laptop	30000
Android Phone	6000
Microcontroller	250
Temperature Sensor	85
Humidity Sensor	400
PM2.5 Sensor	1600
Carbon Monoxide Sensor	350
<b>TOTAL COST</b>	<b>38685</b>

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 fully electronic design because the implementation in the hardware will be using electronic circuits. methodology will introduce how the data is gathered in the device and represented to the users. result and discussion will be providing the user feedback and the actual data given by the device in real situation. The value of this project will be determined in the conclusion based on all the provided data and actual simulation. It is the most important part to prove how this project fulfilled its purpose for the public health awareness.



365

## Chapter 2

366

## LITERATURE REVIEW

367

### Contents

368

369

370

371

372

373

374

375

---

2.1	Temperature Monitoring System . . . . .	12
2.2	Humidity Monitoring System . . . . .	13
2.3	PM <sub>10</sub> Temporal Monitoring . . . . .	15
2.4	Wireless Air Quality Monitoring System . . . . .	15
2.5	Discomfort Index Monitoring System . . . . .	16
2.6	Air Quality Standards . . . . .	17

---



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



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,



420 serial communication, wireless connection and a computer. The data from the sensor  
421 will be transmitted to the microcontroller and transferred to the computer through serial  
422 communication. The computer will transmit the data to the android phone via wireless  
423 connection and the android phone can now control the system depending on the commands  
424 that will be selected. The android can receive data from the humidity sensor, send data  
425 for water sprayer to turn on, send data for stepper motor to work and other commands  
426 that the system is capable of doing. This system ensures the condition of the green house  
427 environment to be in good condition.

428 Other than agricultural applications, studies also shows how air quality such as tem-  
429 perature and humidity affects the health of a human being. Indoor air quality or IAQ is  
430 an important factor that may affect the level of comfort and the health of the people. This  
431 may increase the discomfort index of a human being which may result to difficulties in con-  
432 centration or even headaches. [Folea and Mois, 2015] develop a wireless battery-powered  
433 system for online ambient monitoring. The system has the ability to monitor temperature,  
434 humidity, carbon dioxide level, absolute pressure and intensity of light in the indoor spaces.  
435 The data gathered can be sent through a computer for visualization and can send SMS for  
436 alarms. The system has sensors such as ambient, temperature, humidity and many more  
437 sensors to evaluate the indoor air quality. Wi-Fi connection is used as a data transmission,  
438 from the sensors to the computer, due to the fact that Wi-Fi can be found in almost every  
439 home. The study of indoor air quality will help prevent or solve issues that may affect the  
440 health and the performance of the people.



## 2.3 PM<sub>10</sub> Temporal Monitoring

PM<sub>10</sub> 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<sub>10</sub> 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<sub>10</sub> 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<sub>2.5</sub>, 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.



Another similar study [Hebbar et al., 2014] of an air monitoring device is implemented using a microcontroller where several sensors are placed and data is sent through GSM wirelessly. The design tests the amount of CO<sub>2</sub> levels indoors. It also measures the temperature and humidity of the atmosphere locally. Calibration of the sensors is done by concentrating known amount of a certain gas into a test chamber and determine its offset from the results obtained. The design was tested in a seminar hall and the results obtained showed that the start and end of each class attributed to the increase in CO<sub>2</sub> emission. The design also shows the data through an online GUI.

One similar design, called HazeWatch, is done using several sensors and cloud computing [Hu et al., 2016]. The design is made compact and portable and can be mounted onto a car or bike. Data is harvested using a mobile phone and records the location in real time. Data is then sent wirelessly to cloud-based servers and is interpolated (Inverse Weighing and Ordinary Kriging interpolation) to generate estimates. The data can then be view visually using contour maps of the pollution or gas concentration levels in the area. The results obtained are compared to similar products (*Node* and *SensorDrone*)

## 2.5 Discomfort Index Monitoring System

A research was made about the importance of monitoring and controlling of atmospheric conditions to the efficiency of the performance of the human beings [Noh et al., 2013]. They designed a wireless sensor module that uses a Zigbee communication and sensor module, which consists of temperature, humidity, CO<sub>2</sub> and atmospheric pressure sensor, that maintains a comfortable environment for human beings or to prevent discomfort. The sensor module is the transmitter which delivers the sensor data to the receiver and



the receiver will transmit the filtered or recovered sensor data to a microcontroller board in monitoring the room environment. The room monitoring system is able to provide a comfortable environment for human beings through the wireless sensor network or WSN for monitoring the room environment.

## 2.6 Air Quality Standards

This review shows the different indoor air quality standards set by different countries across the world. The data is collected from documents from different health and environmental organization. This paper can be set as a tool for evaluating acceptable concentrations of different pollutants within an area. The pollutants included in this study are "carbon dioxide ( $\text{CO}_2$ ), carbon monoxide (CO), formaldehyde (HCHO), nitrogen dioxide ( $\text{NO}_2$ ), sulfur dioxide ( $\text{SO}_2$ ), total volatile organic compounds (TVOCs) and particulate matter ( $\text{PM}_{2.5}$  and  $\text{PM}_{10}$ ).” The amount allowable depends on how bad the amount of a certain pollutant exists indoors. The paper also explains different harmful health effects each pollutant has on the human body.





499

## Chapter 3

500

# THEORETICAL CONSIDERATIONS

501

## Contents

502

503

504

---

3.1 Summary . . . . .	20
-----------------------	----

---



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

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

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



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

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

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

### 550 3.1 Summary

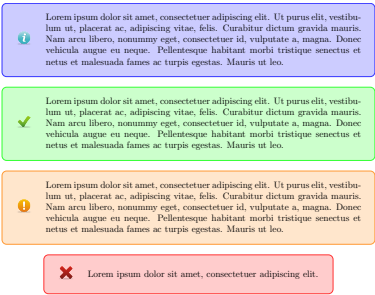


Fig. 3.1 A quadrilateral image example.



551

## Chapter 4

552

# DESIGN CONSIDERATIONS

553

### Contents

554

555

556

---

4.1 Summary . . . . .	24
-----------------------	----

---

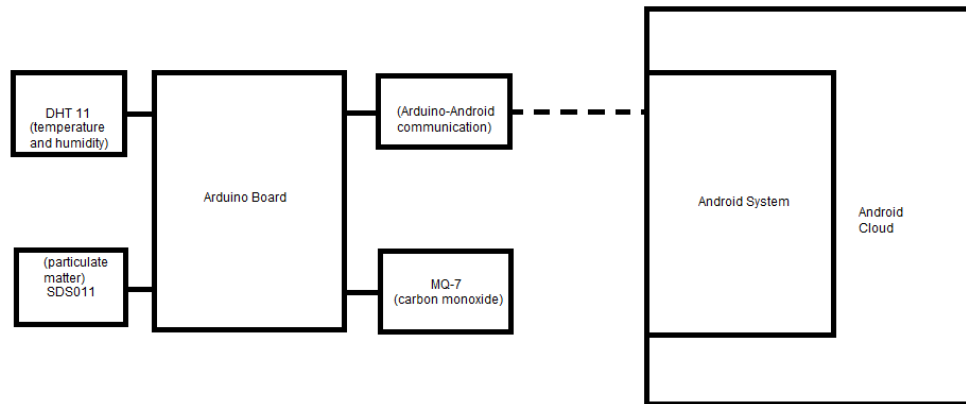


Figure 5.1. System Model of the Project

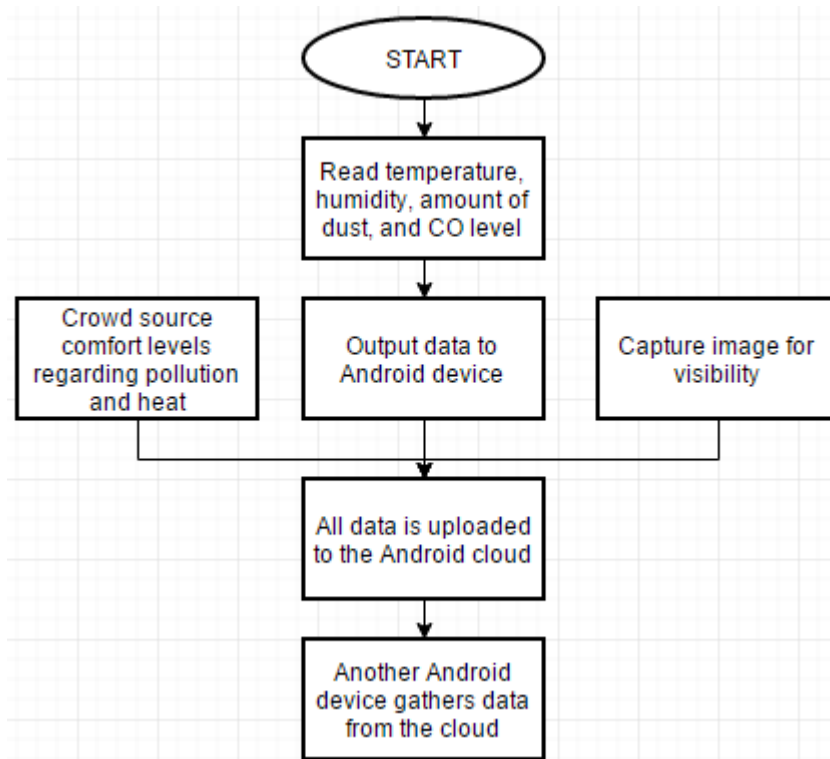


Figure 5.2. System Flowchart

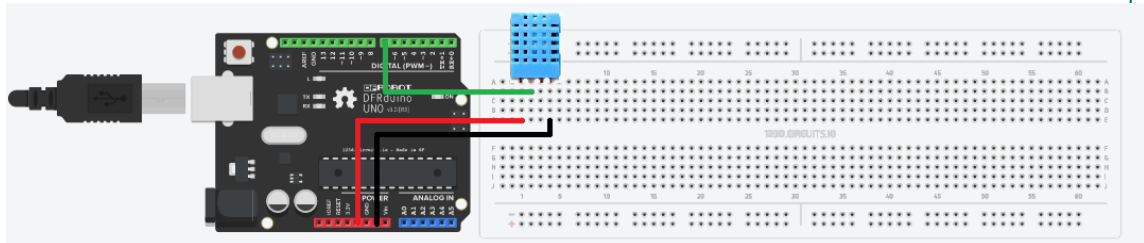


Figure 5.3. Accomplished Circuit Configuration

```

1  #include <dht.h>
2
3  dht DHT;
4
5  #define DHT11_PIN 7
6
7  void setup(){
8      Serial.begin(9600);
9  }
10
11 void loop()
12 {
13     int chk = DHT.read11(DHT11_PIN);
14     Serial.print("Temperature = ");
15     Serial.println(DHT.temperature);
16     Serial.print("Humidity = ");
17     Serial.println(DHT.humidity);
18     delay(1000);
19 }

```

Figure 5.4. Accomplished Code for Temperature and Humidity Gathering



## 583 4.1 Summary

584 According to the system model, the project will make use of an Arduino microcontroller  
585 system that will handle tasks of gathering inputs which are the temperature, humidity,  
586 amount of dust, and amount of carbon monoxide. These data will be transmitted an  
587 Android system. Afterwards, this data can be submitted to the Android cloud in real time.  
588 Each individual Android system in the cloud can make use of the camera to capture the  
589 image of the surroundings in order to get the visibility with the aid of computer vision. A  
590 crowdsourcing element is considered to be added in each system where the user can rank  
591 the amount of discomfort he feels in terms of the heat and air pollution. This information  
592 will be utilized in the cloud.

593 The current accomplishments for the group is the successful gathering of the temperature  
594 and humidity with the use of the Arduino system and the DHT-11 sensor. These values are  
595 rounded to the nearest units value.





596

## Chapter 5

597

## METHODOLOGY

598

### Contents

599

600

601

602

603

---

5.1	Implementation . . . . .	26
5.2	Evaluation . . . . .	28
5.3	Summary . . . . .	30

---



## 604 5.1 Implementation

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

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

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



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

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

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



650

## 5.2 Evaluation

651

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

652

Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec

653

ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus

654

placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.

655

Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla

656

tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue

657

a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.

658

Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit

659

amet ipsum. Nunc quis urna dictum turpis accumsan semper.

660

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

661

Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec

662

ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus

663

placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.

664

Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla

665

tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue

666

a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.

667

Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit

668

amet ipsum. Nunc quis urna dictum turpis accumsan semper.

669

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

670

Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec

671

ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus

672

placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.



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

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

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



696

**5.3 Summary**



697

## Chapter 6

698

# RESULTS AND DISCUSSION

699

## Contents

700

701

702

---

6.1 Summary . . . . .	33
-----------------------	----

---



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

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

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





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

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

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

## 748 6.1 Summary



749

## Chapter 7

750

## CONCLUSIONS, RECOMMENDATIONS,

751

## AND FUTURE DIRECTIVES

752

### Contents

753

754

---

7.1 Concluding Remarks . . . . . 35

755

7.2 Contributions . . . . . 35

756

7.3 Recommendations . . . . . 35

757

7.4 Future Prospects . . . . . 37

---

758



759 **7.1 Concluding Remarks**

760 In this Thesis, . . .

761 **7.2 Contributions**

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

- 764 • the ;
- 765 • the ;
- 766 • the ;

767 **7.3 Recommendations**

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



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

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

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



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

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

## 813 7.4 Future Prospects

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

816 1. the ....

817 2. the ....

818 3. the ....



## REFERENCES

- [Aji Hanggoro and Sari, 2013] Aji Hanggoro, Mahesa Adhitya Putra, R. R. and Sari, R. F. (2013). Green house monitoring and controlling using android mobile application. *Quality in Research 2013*.
- [Chavan and V.Karande, 2014] Chavan, P. C. H. and V.Karande, M. (2014). Wireless monitoring of soil moisture, temperature & humidity using zigbee in agriculture. *International Journal of Engineering Trends and Technology (IJETT)*.
- [Folea and Mois, 2015] Folea, S. C. and Mois, G. (2015). A low-power wireless sensor for online ambient monitoring. *IEEE SENSORS JOURNAL*.
- [Hebbar et al., 2014] Hebbar, S., V. K., K. K. G., Kumar, A., Kumari, A. S. A., Yasasvi, R., Gupta, A. K., Mishra, V., Amrutur, B., and Bhat, N. (2014). System engineering and deployment of envirobat an urban air pollution monitoring device. In *Electronics, Computing and Communication Technologies (IEEE CONECCT), 2014 IEEE International Conference on*, pages 1–6.
- [Hu et al., 2016] Hu, K., Sivaraman, V., Luxan, B. G., and Rahman, A. (2016). Design and evaluation of a metropolitan air pollution sensing system. *IEEE Sensors Journal*, 16(5):1448–1459.
- [ISO, 2009] ISO (2009). 80000-2. *Quantities and units–Part 2: Mathematical signs and symbols to be used in the natural sciences and technology*.
- [Mohamed Abd El-Latif Mowad, 2014] Mohamed Abd El-Latif Mowad, Ahmed Fathy, A. H. (2014). Smart home automated control system using android application and microcontroller. *International Journal of Scientific & Engineering Research*.
- [Noh et al., 2013] Noh, S.-K., Kim, K.-S., and Ji, Y.-K. (2013). Design of a room monitoring system for wireless sensor networks. *International Journal of Distributed Sensor Networks*.
- [Oetiker et al., 2014] Oetiker, T., Partl, H., Hyna, I., and Schlegl, E. (2014). *The Not So Short Introduction to L<sup>A</sup>T<sub>E</sub>X 2<sub>ε</sub> Or L<sup>A</sup>T<sub>E</sub>X 2<sub>ε</sub> in 157 minutes*. n.a.
- [Reilly et al., 2015] Reilly, K. M., Birner, M. T., and Johnson, N. G. (2015). Measuring air quality using wireless self-powered devices. In *Global Humanitarian Technology Conference (GHTC), 2015 IEEE*, pages 267–272.
- [Wong et al., 2007] Wong, C. J., MatJafri, M. Z., Abdullah, K., Lim, H. S., and Low, K. L. (2007). Temporal air quality monitoring using surveillance camera. In *2007 IEEE International Geoscience and Remote Sensing Symposium*, pages 2864–2868.



# Appendix A ANSWERS TO QUESTIONS TO THIS THESIS

## Contents

A1	How important is the problem to practice? . . . . .	40
A2	How will you know if the solution/s that you will achieve would be better than existing ones? . . . . .	40
A2.1	How will you measure the improvement/s? . . . . .	40
A2.1.1	What is/are your basis/bases for the improvement/s? . .	41
A2.1.2	Why did you choose that/those basis/bases? . . . . .	41
A2.1.3	How significant are your measure/s of the improvement/s? .	41
A3	What is the difference of the solution/s from existing ones? . . . . .	42
A3.1	How is it different from previous and existing ones? . . . . .	42
A4	What are the assumptions made (that are behind for your proposed solution to work)? . . . . .	42
A4.1	Will your proposed solution/s be sensitive to these assumptions? .	43
A4.2	Can your proposed solution/s be applied to more general cases when some of the assumptions are eliminated? If so, how? . . . . .	43
A5	What is the necessity of your approach / proposed solution/s? . . . . .	43
A5.1	What will be the limits of applicability of your proposed solution/s? .	44
A5.2	What will be the message of the proposed solution to technical people? How about to non-technical managers and business men? .	44
A6	How will you know if your proposed solution/s is/are correct? . . . . .	44
A6.1	Will your results warrant the level of mathematics used (i.e., will the end justify the means)? . . . . .	45
A7	Is/are there an/_ alternative way/s to get to the same solution/s? . . . . .	45
A7.1	Can you come up with illustrating examples, or even better, counter examples to your proposed solution/s? . . . . .	45
A7.2	Is there an approximation that can arrive at the essentially the same proposed solution/s more easily? . . . . .	46
A8	If you were the examiner of your proposal, how would you present the proposal in another way? . . . . .	46
A8.1	What are the weaknesses of your proposal? . . . . .	46



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

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

## 896 **A2 How will you know if the solution/s that you will** 897 **achieve would be better than existing ones?**

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

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

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





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

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

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

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

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

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



947

948

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

949

950

951

952

953

954

955

956

957

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

958

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

959

960

961

962

963

964

965

966

967

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

968

969

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

970

971

972

973

974

975

976

977

978

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



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

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

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

993 Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem.  
 994 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec  
 995 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus  
 996 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.  
 997 Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla  
 998 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue  
 999 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.  
 1000 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit  
 1001 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

1002 **A5 What is the necessity of your approach / pro-**  
 1003 **posed solution/s?**

1004 Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem.  
 1005 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec  
 1006 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus  
 1007 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.  
 1008 Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla  
 1009 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue  
 1010 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.



1011 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit  
1012 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

1013 **A5.1 What will be the limits of applicability of your proposed so-**  
1014 **lution/s?**

1015 Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem.  
1016 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec  
1017 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus  
1018 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.  
1019 Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla  
1020 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue  
1021 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.  
1022 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit  
1023 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

1024 **A5.2 What will be the message of the proposed solution to**  
1025 **technical people? How about to non-technical managers**  
1026 **and business men?**

1027 Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem.  
1028 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec  
1029 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus  
1030 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.  
1031 Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla  
1032 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue  
1033 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.  
1034 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit  
1035 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

1036 **A6 How will you know if your proposed solution/s**  
1037 **is/are correct?**

1038 Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem.  
1039 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec  
1040 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus  
1041 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.  
1042 Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla



1043 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue  
1044 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.  
1045 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit  
1046 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

1047 **A6.1 Will your results warrant the level of mathematics used**  
1048 **(i.e., will the end justify the means)?**

1049 Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem.  
1050 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec  
1051 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus  
1052 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.  
1053 Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla  
1054 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue  
1055 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.  
1056 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit  
1057 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

1058 **A7 Is/are there an/\_ alternative way/s to get to the**  
1059 **same solution/s?**

1060 Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem.  
1061 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec  
1062 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus  
1063 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.  
1064 Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla  
1065 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue  
1066 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.  
1067 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit  
1068 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

1069 **A7.1 Can you come up with illustrating examples, or even bet-**  
1070 **ter, counter examples to your proposed solution/s?**

1071 Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem.  
1072 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec  
1073 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus  
1074 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.



1075 Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla  
1076 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue  
1077 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.  
1078 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit  
1079 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

## 1080 **A7.2 Is there an approximation that can arrive at the essen-** 1081 **tially the same proposed solution/s more easily?**

1082 Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem.  
1083 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec  
1084 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus  
1085 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.  
1086 Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla  
1087 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue  
1088 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.  
1089 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit  
1090 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

## 1091 **A8 If you were the examiner of your proposal, how** 1092 **would you present the proposal in another way?**

1093 Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem.  
1094 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec  
1095 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus  
1096 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.  
1097 Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla  
1098 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue  
1099 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.  
1100 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit  
1101 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

## 1102 **A8.1 What are the weaknesses of your proposal?**

1103 Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem.  
1104 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec  
1105 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus  
1106 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.



De La Salle University

1107 Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla  
1108 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue  
1109 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.  
1110 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit  
1111 amet ipsum. Nunc quis urna dictum turpis accumsan semper.



De La Salle University

1112

## **Appendix B**

1113

## **USAGE EXAMPLES**





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

## B1 Equations

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

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

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

Other example equations are as follows.

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

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

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



1127

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

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

```

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

```



## B2 Notations

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

### Math alphabets

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

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

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

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

Do the math alphabets match?

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

### Vector symbols

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

### Matrix symbols

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

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



1142

**Tensor symbols**

1143

Symbols for tensors are sans-serif bold italic,

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

1144

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

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



## Bold math version

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

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

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

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

Do the math alphabets match?

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

## Vector symbols

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

## Matrix symbols

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

## Tensor symbols

Symbols for tensors are sans-serif bold italic,

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

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

$$D = \epsilon_0 \epsilon_r E$$

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



1159 The verbatim  $\text{\LaTeX}$  code of Sec. B2 is in List. B.2.

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

```

1160 1 % A teststring with Latin and Greek letters::
1161 2 \newcommand{\teststring}{%
1162 3 % capital Latin letters
1163 4 % A,B,C,
1164 5 A,B,
1165 6 % capital Greek letters
1166 7 %\Gamma,\Delta,\Theta,\Lambda,\Xi,\Pi,\Sigma,\Upsilon,\Phi,\Psi,
1167 8 \Gamma,\Delta,\Theta,\Lambda,\Xi,\Pi,\Sigma,\Phi,\Psi,\Omega,
1168 9 % small Greek letters
1169 10 \alpha,\beta,\pi,\nu,\omega,
1170 11 % small Latin letters:
1171 12 % compare \nu, \omega, v, and w
1172 13 v,w,
1173 14 % digits
1174 15 0,1,9
1175 16 }
1176 17
1177 18
1178 19 \subsection*{Math alphabets}
1179 20
1180 21 If there are other symbols in place of Greek letters in a math
1181 22 alphabet, it uses T1 or OT1 font encoding instead of OML.
1182 23
1183 24 \begin{eqnarray*}
1184 25 \mbox{\mathnormal} & & \mbox{\teststring} \\
1185 26 \mbox{\mathit} & & \mbox{\mathit{\teststring}} \\
1186 27 \mbox{\mathrm} & & \mbox{\mathrm{\teststring}} \\
1187 28 \mbox{\mathbf} & & \mbox{\mathbf{\teststring}} \\
1188 29 \mbox{\mathsf} & & \mbox{\mathsf{\teststring}} \\
1189 30 \mbox{\mathtt} & & \mbox{\mathtt{\teststring}} \\
1190 31 \end{eqnarray*}
1191 32 New alphabets bold-italic, sans-serif-italic, and sans-serif-bold-
1192 33 italic.
1193 34 \begin{eqnarray*}
1194 35 \mbox{\mathbfit} & & \mbox{\mathbfit{\teststring}} \\
1195 36 \mbox{\mathsf fit} & & \mbox{\mathsf fit{\teststring}} \\
1196 37 \mbox{\mathsf bfit} & & \mbox{\mathsf bfit{\teststring}} \\
1197 38 \end{eqnarray*}
1198 39 %
1199 40 Do the math alphabets match?
1200 41 $
1201 42 \mathnormal {a x \alpha \omega}
1202 43 \mathbfit {a x \alpha \omega}
1203 44 \mathsf bfit {a x \alpha \omega}
1204 45 \quad
1205 46 \mathsf bfit {T C \Theta \Gamma}
1206 47 \mathbfit {T C \Theta \Gamma}
1207 48 \mathnormal {T C \Theta \Gamma}
1208 49 $
1209 50
1210 51 \subsection*{Vector symbols}
1211 52

```



```

1214 53 Alphabetic symbols for vectors are boldface italic,
1215 54  $\vec{\lambda} = \vec{e}_1 \cdot \vec{a}$ ,
1216 55 while numeric ones (e.g. the zero vector) are bold upright,
1217 56  $\vec{a} + \vec{0} = \vec{a}$ .
1218 57
1219 58 \subsection*{Matrix symbols}
1220 59
1221 60 Symbols for matrices are boldface italic, too:%
1222 61 \footnote{However, matrix symbols are usually capital letters whereas
1223 62 vectors
1224 62 are small ones. Exceptions are physical quantities like the force
1225 63 vector  $\vec{F}$  or the electrical field  $\vec{E}$ .%
1226 64 }
1227 65  $\Lambda = E \cdot A$ .
1228 66
1229 67
1230 68 \subsection*{Tensor symbols}
1231 69
1232 70 Symbols for tensors are sans-serif bold italic,
1233 71
1234 72 \[
1235 73 \quad \text{\texttt{\textbf{tensorsym}\{alpha\}}} = \text{\texttt{\textbf{tensorsym}\{e\}}} \cdot \text{\texttt{\textbf{tensorsym}\{a\}}}
1236 74 \quad \text{\texttt{\textbf{quad}}} \quad \text{\texttt{\textbf{Longleftarrow}}} \quad \text{\texttt{\textbf{quad}}}
1237 75 \quad \text{\texttt{\textbf{alpha}_{ijl}}} = \text{\texttt{\textbf{e}_{ijk}}} \cdot \text{\texttt{\textbf{a}_{kl}}}.
1238 76 \]
1239 77
1240 78
1241 79 The permittivity tensor describes the coupling of electric field and
1242 80 displacement: \[
1243 81 \vec{D} = \epsilon_0 \text{\texttt{\textbf{tensorsym}\{\epsilon\}}}_{\text{\texttt{\textbf{r}}}} \vec{E} \]
1244 82
1245 83
1246 84
1247 85 \newpage
1248 86 \subsection*{Bold math version}
1249 87
1250 88 The ‘‘bold’’ math version is selected with the commands
1251 89 \verb+\boldmath+ or \verb+\mathversion{bold}+
1252 90
1253 91 {\boldmath
1254 92 \begin{eqnarray*}
1255 93 \quad \text{\texttt{\textbf{mbox}\{mathnormal\}}} & & \text{\texttt{\textbf{teststring}}} \\
1256 94 \quad \text{\texttt{\textbf{mbox}\{mathit\}}} & & \text{\texttt{\textbf{mathit}\{teststring\}}} \\
1257 95 \quad \text{\texttt{\textbf{mbox}\{mathrm\}}} & & \text{\texttt{\textbf{mathrm}\{teststring\}}} \\
1258 96 \quad \text{\texttt{\textbf{mbox}\{mathbf\}}} & & \text{\texttt{\textbf{mathbf}\{teststring\}}} \\
1259 97 \quad \text{\texttt{\textbf{mbox}\{mathsf\}}} & & \text{\texttt{\textbf{mathsf}\{teststring\}}} \\
1260 98 \quad \text{\texttt{\textbf{mbox}\{mathtt\}}} & & \text{\texttt{\textbf{mathtt}\{teststring\}}}
1261 99 \end{eqnarray*}
1262 100 \quad \text{New alphabets bold-italic, sans-serif-italic, and sans-serif-bold-}
1263 101 \quad \text{italic.}
1264 102 \begin{eqnarray*}
1265 103 \quad \text{\texttt{\textbf{mbox}\{mathbfit\}}} & & \text{\texttt{\textbf{mathbfit}\{teststring\}}} \\
1266 104 \quad \text{\texttt{\textbf{mbox}\{mathsf\}}} & & \text{\texttt{\textbf{mathsf}\{teststring\}}} \\
1267 105 \quad \text{\texttt{\textbf{mbox}\{mathsfbfit\}}} & & \text{\texttt{\textbf{mathsfbfit}\{teststring\}}}
1268 106 \end{eqnarray*}
1269 107 \%
1270 108 Do the math alphabets match?

```



# De La Salle University

```

1271 108
1272 109 $
1273 110 \mathnormal {a x \alpha \omega}
1274 111 \mathbfit {a x \alpha \omega}
1275 112 \mathsfbfit{a x \alpha \omega}
1276 113 \quad
1277 114 \mathsfbfit{T C \Theta \Gamma}
1278 115 \mathbfit {T C \Theta \Gamma}
1279 116 \mathnormal {T C \Theta \Gamma}
1280 117 $
1281 118
1282 119 \subsection*{Vector symbols}
1283 120
1284 121 Alphabetic symbols for vectors are boldface italic,
1285 122 $\vec{\lambda}=\vec{e}_{1}\cdot\vec{a}$,
1286 123 while numeric ones (e.g. the zero vector) are bold upright,
1287 124 $\vec{a} + \vec{0} = \vec{a}$.
1288 125
1289 126
1290 127
1291 128
1292 129 \subsection*{Matrix symbols}
1293 130
1294 131 Symbols for matrices are boldface italic, too:%
1295 132 \footnote{However, matrix symbols are usually capital letters whereas
1296 133 vectors
1297 134 are small ones. Exceptions are physical quantities like the force
1298 135 vector $\vec{F}$ or the electrical field $\vec{E}$.%
1299 136 }
1300 137 $\matrixsym{\Lambda}=\matrixsym{E}\cdot\matrixsym{A}$.
1301 138
1302 139 \subsection*{Tensor symbols}
1303 140
1304 141 Symbols for tensors are sans-serif bold italic,
1305 142
1306 143 \[
1307 144 \tensorsym{\alpha} = \tensorsym{e}\cdot\tensorsym{a}
1308 145 \quad \Longrightarrow \quad
1309 146 \alpha_{ijl} = e_{ijk}\cdot a_{kl}.
1310 147 \]
1311 148
1312 149 The permittivity tensor describes the coupling of electric field and
1313 150 displacement: \[
1314 151 \vec{D}=\epsilon_{0}\tensorsym{\epsilon}_{\mathrm{r}}\vec{E}\]
1315 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).



- 1347 • Provide your own link text: style sheet.

1348 The verbatim  $\text{\LaTeX}$  code of Sec. B3 is in List. B.3.

### Listing B.3: Sample $\text{\LaTeX}$ code for abbreviations usage

```

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

```



## B4 Glossary

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

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

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

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

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

```

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



1363

**B5 Figure**

1364

1365

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

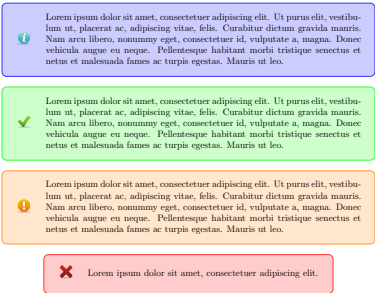


Fig. B.1 A quadrilateral image example.

1366  
1367

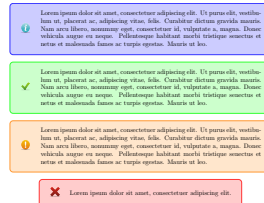
Fig. B.1 is a gray box enclosed by a dark border. List. B.5 shows the corresponding  $\text{\LaTeX}$  code.

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

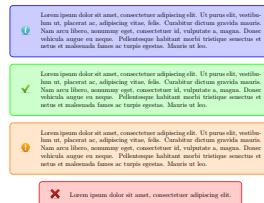
```
1 \begin{figure}[!htbp]
2   \centering
3   \includegraphics[width=0.5\textwidth]{example}
4   \caption{A quadrilateral image example.}
5   \label{fig:example}
6 \end{figure}
7 \cleardoublepage
8
9 Fig.~\ref{fig:example} is a gray box enclosed by a dark border. List.~\ref{lst:onefig} shows the corresponding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



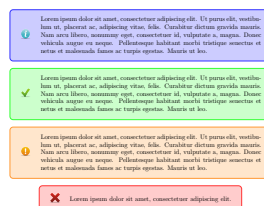
# De La Salle University



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



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

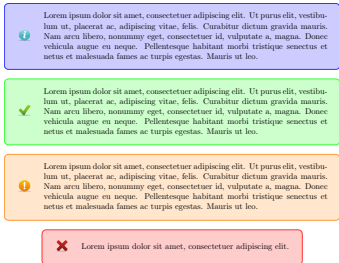


(c) A sub-figure in the bottom row.

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

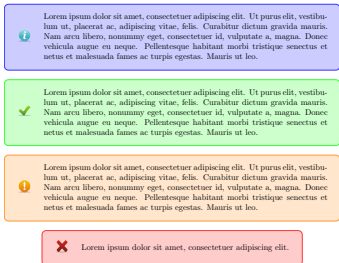
```
1 \begin{figure}[!htbp]
2 \centering
3 \subbottom[A sub-figure in the top row.]{
4 \includegraphics[width=0.35\textwidth]{example}
5 \label{fig:top}
6 }
7 \vfill
8 \subbottom[A sub-figure in the middle row.]{
9 \includegraphics[width=0.35\textwidth]{example}
10 \label{fig:mid}
11 }
12 \vfill
13 \subbottom[A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

B. Usage Examples



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

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



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

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

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



Listing B.7: Sample  $\text{\LaTeX}$  code for the four figures

```

1 \begin{figure}[!htbp]
2 \centering
3 \subbottom[A sub-figure in the upper-left corner.]{
4 \includegraphics[width=0.45\textwidth]{example}
5 \label{fig:upprleft}
6 }
7 \hfill
8 \subbottom[A sub-figure in the upper-right corner.]{
9 \includegraphics[width=0.45\textwidth]{example}
10 \label{fig:uppright}
11 }
12 \vfill
13 \subbottom[A sub-figure in the lower-left corner.]{
14 \includegraphics[width=0.45\textwidth]{example}
15 \label{fig:lowerleft}
16 }
17 \hfill
18 \subbottom[A sub-figure in the lower-right corner]{
19 \includegraphics[width=0.45\textwidth]{example}
20 \label{fig:lowright}
21 }
22 \caption{Four figures in each corner. See List.\ref{lst:fourfigs} for
23 the corresponding \LaTeX \ code.}
24 \label{fig:fourfig}
25 \end{figure}

```



## B6 Table

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

TABLE B.1 FEASIBLE TRIPLES FOR HIGHLY VARIABLE GRID

Time (s)	Triple chosen	Other feasible triples
0	(1, 11, 13725)	(1, 12, 10980), (1, 13, 8235), (2, 2, 0), (3, 1, 0)
2745	(1, 12, 10980)	(1, 13, 8235), (2, 2, 0), (2, 3, 0), (3, 1, 0)
5490	(1, 12, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
8235	(1, 12, 16470)	(1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0)
10980	(1, 12, 16470)	(1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0)
13725	(1, 12, 16470)	(1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0)
16470	(1, 13, 16470)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
19215	(1, 12, 16470)	(1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0)
21960	(1, 12, 16470)	(1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0)
24705	(1, 12, 16470)	(1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0)
27450	(1, 12, 16470)	(1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0)
30195	(2, 2, 2745)	(2, 3, 0), (3, 1, 0)
32940	(1, 13, 16470)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
35685	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
38430	(1, 13, 10980)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
41175	(1, 12, 13725)	(1, 13, 10980), (2, 2, 2745), (2, 3, 0), (3, 1, 0)
43920	(1, 13, 10980)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
46665	(2, 2, 2745)	(2, 3, 0), (3, 1, 0)
49410	(2, 2, 2745)	(2, 3, 0), (3, 1, 0)
52155	(1, 12, 16470)	(1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0)
54900	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
57645	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
60390	(1, 12, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
63135	(1, 13, 16470)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
65880	(1, 13, 16470)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
68625	(2, 2, 2745)	(2, 3, 0), (3, 1, 0)
71370	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
74115	(1, 12, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
76860	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
79605	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
82350	(1, 12, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
85095	(1, 12, 13725)	(1, 13, 10980), (2, 2, 2745), (2, 3, 0), (3, 1, 0)
87840	(1, 13, 16470)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
90585	(1, 13, 16470)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
93330	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
96075	(1, 13, 16470)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
98820	(1, 13, 16470)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
101565	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
104310	(1, 13, 16470)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
107055	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
109800	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
112545	(1, 12, 16470)	(1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0)
115290	(1, 13, 16470)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
118035	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
120780	(1, 13, 16470)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
123525	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)

*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)



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

Listing B.8: Sample  $\text{\LaTeX}$  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}{\textit{Continued from previous page}} \\
13 \hline
14 \hline
15 \textbf{Time (s)} &
16 \textbf{Triple chosen} &
17 \textbf{Other feasible triples} \\
18 \hline
19 \endhead
20 \hline
21 \multicolumn{3}{r}{\textit{Continued on next page}} \\
22 \endfoot
23 \hline
24 \endlastfoot
25 \hline
26
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)

```



```

1426 43 41175 & (1, 12, 13725) & (1, 13, 10980), (2, 2, 2745), (2, 3, 0), (3, 1,
1427      0) \\
1428 44 43920 & (1, 13, 10980) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1429 45 46665 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
1430 46 49410 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
1431 47 52155 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1,
1432      0) \\
1433 48 54900 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1434 49 57645 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1435 50 60390 & (1, 12, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1436 51 63135 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1437 52 65880 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1438 53 68625 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
1439 54 71370 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1440 55 74115 & (1, 12, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1441 56 76860 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1442 57 79605 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1443 58 82350 & (1, 12, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1444 59 85095 & (1, 12, 13725) & (1, 13, 10980), (2, 2, 2745), (2, 3, 0), (3, 1,
1445      0) \\
1446 60 87840 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1447 61 90585 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1448 62 93330 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1449 63 96075 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1450 64 98820 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1451 65 101565 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1452 66 104310 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1453 67 107055 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1454 68 109800 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1455 69 112545 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3,
1456      1, 0) \\
1457 70 115290 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1458 71 118035 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1459 72 120780 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1460 73 123525 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1461 74 126270 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3,
1462      1, 0) \\
1463 75 129015 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
1464 76 131760 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
1465 77 134505 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1466 78 137250 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1467 79 139995 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
1468 80 142740 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
1469 81 145485 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3,
1470      1, 0) \\
1471 82 148230 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
1472 83 150975 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1473 84 153720 & (1, 12, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1474 85 156465 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1475 86 159210 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1476 87 161955 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1477 88 164700 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1478 89 \end{tabularx}
1479 90 }
1480 91 \end{center}

```



1482

**B7    Algorithm or Pseudocode Listing**

1483

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

1484

1485

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

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

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

**Ensure:**  $y = x^n$

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

Listing B.9: Sample L<sup>A</sup>T<sub>E</sub>X code for algorithm or pseudocode listing usage

```

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

```







1489

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

Listing B.11: Sample  $\text{\LaTeX}$  code for program listing

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



## B9 Referencing

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

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

Listing B.12: Sample  $\LaTeX$  code for referencing sections

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

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



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



### 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.
```

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



## B10 Index

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

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

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

Listing B.15: Sample  $\text{\LaTeX}$  code for Index usage

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



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

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

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

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



## Virtex UltraScale FPGA Feature Summary

Table 6: Virtex UltraScale FPGA Feature Summary

	VU065	VU080	VU095	VU125	VU160	VU190	VU440
Logic Cells	626,640	780,000	940,800	1,253,280	1,621,200	1,879,920	4,432,680
CLB Flip-Flops	716,160	891,424	1,075,200	1,432,320	1,852,800	2,148,480	5,065,920
CLB LUTs	358,080	445,712	537,600	716,160	926,400	1,074,240	2,532,960
Maximum Distributed RAM (Mb)	4.8	3.9	4.8	9.7	12.7	14.5	28.7
Block RAM/FIFO w/ECC (36Kb each)	1,260	1,421	1,728	2,520	3,276	3,780	2,520
Total Block RAM (Mb)	44.3	50.0	60.8	88.6	115.2	132.9	88.6
CMT (1 MMCM, 2 PLLs)	10	16	16	20	30	30	30
I/O DLLs	40	64	64	80	120	120	120
Fractional PLLs	5	8	8	10	15	15	0
Maximum HP I/Os <sup>(1)</sup>	468	780	780	780	650	650	1,404
Maximum HR I/Os <sup>(2)</sup>	52	52	52	104	52	52	52
DSP Slices	600	672	768	1,200	1,560	1,800	2,880
System Monitor	1	1	1	2	3	3	3
PCIe Gen3 x8	2	4	4	4	5	6	6
150G Interlaken	3	6	6	6	8	9	0
100G Ethernet	3	4	4	6	9	9	3
GTH 16.3Gb/s Transceivers	20	32	32	40	52	60	48
GTY 30.5Gb/s Transceivers	20	32	32	40	52	60	0

**Notes:**

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



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

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

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

**Notes:**

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





## Virtex UltraScale+ FPGA Feature Summary

Table 8: Virtex UltraScale+ FPGA Feature Summary

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

**Notes:**

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

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

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

Package (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 <sup>(4)</sup>						832, 52
FLVB2104	47.5x47.5		702, 76	702, 76	702, 76	624, 76	
FHVB2104	52.5x52.5 <sup>(4)</sup>						702, 76
FLVC2104	47.5x47.5		416, 80	416, 80	416, 104	416, 96	
FHVC2104	52.5x52.5 <sup>(4)</sup>						416, 104
FLVA2577	52.5x52.5				448, 120	448, 96	448, 128

**Notes:**

1. Go to [Ordering Information](#) for package designation details.
2. All packages have 1.0mm ball pitch.
3. Packages with the same last letter and number sequence, e.g., A2104, are footprint compatible with all other UltraScale devices with the same sequence. The footprint compatible devices within this family are outlined.
4. These 52.5x52.5mm overhang packages have the same PCB ball footprint as the corresponding 47.5x47.5mm packages (i.e., the same last letter and number sequence) and are footprint compatible.



## Appendix C

### PUBLICATION LIST AND AWARD

#### Journal

1. ...

2. ...

#### Conference

1. ...

2. ...



# De La Salle University

1554

## Others

1555

1. ...

1556

2. ...

1557

## Award

1558

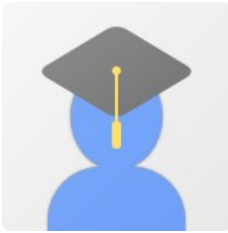
1. ...

1559

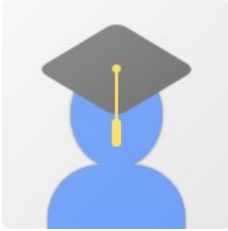
2. ...



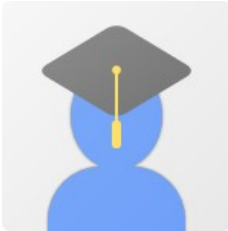
## Appendix D VITA



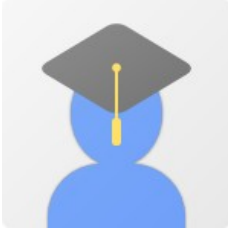
Junlae Cheong is a sixth year student at De La Salle University. He is currently taking up his B.Sc. Computer Engineering studies. His strengths in the field are electronics circuit design and configuration. His fields of interest are electronics hardware and computer microprocessor.



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



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



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



1575 programmed electronic circuits that includes microcontrollers. His strengths in the field are  
1576 microcontroller simulation and programming.



## INDEX

1577	contributions, 35
1578	Fourier operator, 77
1579	Fredholm integral, 77