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Development of Remote Controlled Bluetooth Mobile Robot with Live Video Feedback 2 3 A Thesis 4 Presented to the Faculty of the 5 Department of Electronics and Communications Engineering 6 Gokongwei College of Engineering 7 De La Salle University 8 9 In Partial Fulfillment of the 10 Requirements for the Degree of 11 Bachelor of Science in Computer Engineering 12 13 by 14 CEPRIA, Kevin Jeff T. 15 ECO, Lance Randall L. 16 LIWAG, Ryan Joshua H. 17 RAPIO, Anfernee S. 18 19

May, 2016



ORAL DEFENSE RECOMMENDATION SHEET

This thesis, entitled **Development of Remote Controlled Bluetooth Mobile Robot with Live Video Feedback**, prepared and submitted by thesis group, Kevin and Friends, composed of:

CEPRIA, Kevin Jeff T. ECO, Lance Randall L. LIWAG, Ryan Joshua H. RAPIO, Anfernee S.

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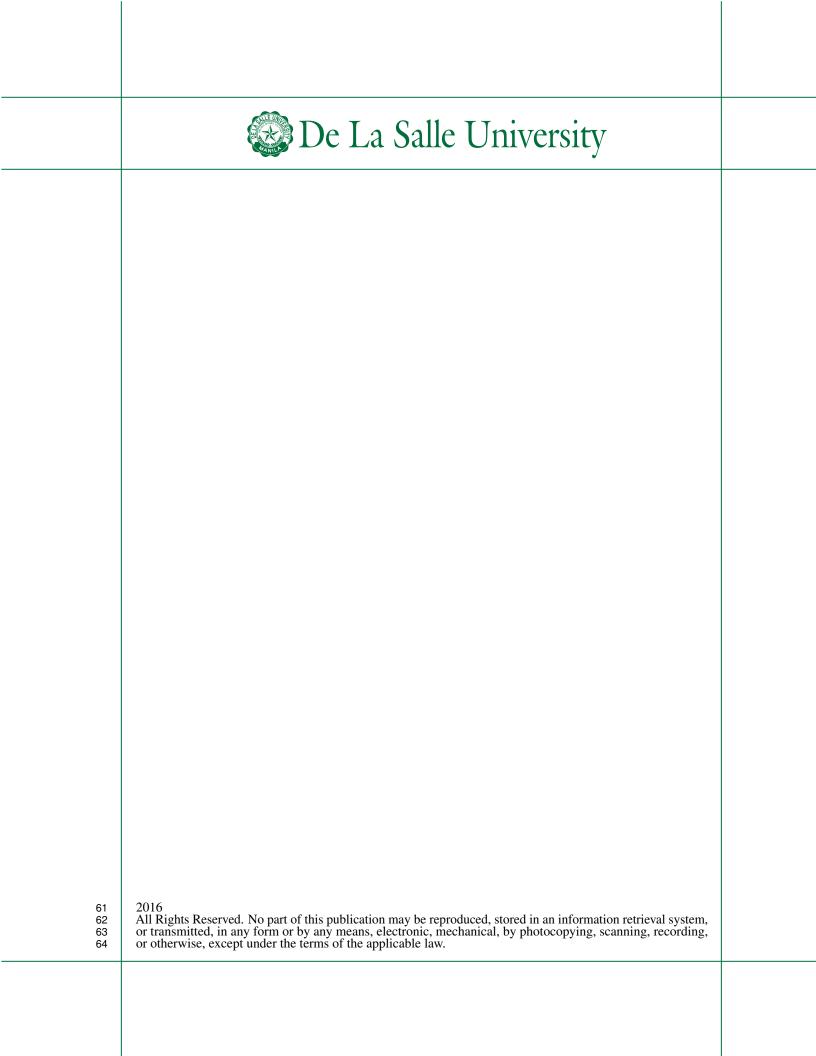
in partial fulfillment of the requirements for the degree of **Bachelor of Science in Computer Engineering** (**BS-CPE**) has been examined and is recommended for acceptance and approval for **ORAL DEFENSE**.

Engr. Melvin K. Cabatuan

Adviser

May 29, 2016

De La Salle University THESIS APPROVAL SHEET This thesis entitled Development of Remote Controlled Bluetooth Mobile Robot with 40 Live Video Feedback, prepared and submitted by: 41 42 CEPRIA, Kevin Jeff T. 43 ECO, Lance Randall L. 44 LIWAG, Ryan Joshua H. 45 RAPIO, Anfernee S. 46 47 with group number Kevin and Friends in partial fulfillment of the requirements for the 48 degree of Bachelor of Science in Computer Engineering (BS-CPE) has been examined 49 and is recommended for acceptance and approval. 50 51 PANEL OF EXAMINERS 52 53 Engr. Donabel de Veas-Abuan 54 Chair Engr. Jay Robert del Rosario Dr. Aaron Africa 56 Member Member 57 Engr. Melvin K. Cabatuan 58 Adviser Date: May 29, 2016 60



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ACKNOWLEDGMENT

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

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68 ABSTRACT

- Keep your abstract short by giving the gist/nutshell of your thesis.
- 70 *Index Terms*—alloy system, characterization, InP, InGaAs.



TABLE OF CONTENTS

Oran De	efense Recommendation Sheet	ii
Thesis A	Approval Sheet	iii
Acknov	vledgment	v
Abstrac	et .	vi
Table of	f Contents	vii
List of 1	Figures	X
List of	Tables	xi
Abbrev	iations	xii
Notatio	n	xiii
Glossar	${f y}$	xiv
Listings		XV
Chapte	r 1 INTRODUCTION	1
1.1	Background of the Study	2
1.2	Prior Studies	4
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	Overview	6
Chapte	r 2 LITERATURE REVIEW	7
2.1	Summary	10



96	Chapter	· 3 THEORETICAL CONSIDERATIONS	11
97	3.1	Summary	13
98	Chapte	4 DESIGN CONSIDERATIONS	15
99	4.1	Summary	17
100	Chapte	5 METHODOLOGY	18
101	5.1	Implementation	19
102	5.2	Evaluation	21
103	5.3	Summary	23
104	Chapte	6 RESULTS AND DISCUSSION	24
105	6.1	Summary	26
106	Chapter	7 CONCLUSIONS, RECOMMENDATIONS, AND FUTURE DIREC-	
107		TIVES	27
108	7.1	Concluding Remarks	28
109	7.2	Contributions	28
110	7.3	Recommendations	28
111	7.4	Future Prospects	30
440	Defenen	000	31
112	Referen	ces	31
		ix A ANSWERS TO QUESTIONS TO THIS THESIS	32
112 113 114			
113	Append	ix A ANSWERS TO QUESTIONS TO THIS THESIS	32 33
113 114 115	Append A1	ix A ANSWERS TO QUESTIONS TO THIS THESIS How important is the problem to practice?	32
113 114 115 116	Append A1	ix A ANSWERS TO QUESTIONS TO THIS THESIS How important is the problem to practice?	32 33 33 33
113 114 115 116 117	Append A1	ix A ANSWERS TO QUESTIONS TO THIS THESIS How important is the problem to practice?	32 33 33 33 34
113 114	Append A1	ix A ANSWERS TO QUESTIONS TO THIS THESIS How important is the problem to practice?	32 33 33 34 34
113 114 115 116 117 118	Append A1	ix A ANSWERS TO QUESTIONS TO THIS THESIS How important is the problem to practice?	32 33 33 33 34
113 114 115 116 117 118	Append A1	ix A ANSWERS TO QUESTIONS TO THIS THESIS How important is the problem to practice?	32 33 33 34 34
113 114 115 116 117 118 119	Append A1 A2	ix A ANSWERS TO QUESTIONS TO THIS THESIS How important is the problem to practice?	32 33 33 34 34 34
113 114 115 116 117 118 119 120	Append A1 A2	ix A ANSWERS TO QUESTIONS TO THIS THESIS How important is the problem to practice?	32 33 33 34 34 34 35 35
113 114 115 116 117 118 119 120 121 122	Append A1 A2	ix A ANSWERS TO QUESTIONS TO THIS THESIS How important is the problem to practice?	32 33 33 34 34 34 35
113 114 115 116 117 118 119 120 121	Append A1 A2	ix A ANSWERS TO QUESTIONS TO THIS THESIS How important is the problem to practice?	32 33 33 34 34 34 35 35
113 114 115 116 117 118 119 120 121 122 123 124	Append A1 A2	ix A ANSWERS TO QUESTIONS TO THIS THESIS How important is the problem to practice?	32 33 33 34 34 35 35 35 36
113 114 115 116 117 118 119 120 121 122 123 124 125	Append A1 A2 A3 A4	ix A ANSWERS TO QUESTIONS TO THIS THESIS How important is the problem to practice? How will you know if the solution/s that you will achieve would be better than existing ones? A2.1 How will you measure the improvement/s? A2.1.1 What is/are your basis/bases for the improvement/s? A2.1.2 Why did you choose that/those basis/bases? A2.1.3 How significant are your measure/s of the improvement/s? What is the difference of the solution/s from existing ones? A3.1 How is it different from previous and existing ones? What are the assumptions made (that are behind for your proposed solution to work)? A4.1 Will your proposed solution/s be sensitive to these assumptions? A4.2 Can your proposed solution/s be applied to more general cases when some of the assumptions are eliminated? If so, how?	32 33 33 34 34 34 35 35 36
113 114 115 116 117 118 119 120 121 122 123 124 125 126	Append A1 A2	ix A ANSWERS TO QUESTIONS TO THIS THESIS How important is the problem to practice?	32 33 33 34 34 35 35 35 36



130		A5.2 What will be the message of the proposed solution to technical	
131		people? How about to non-technical managers and business men?	37
132	A6	How will you know if your proposed solution/s is/are correct?	37
133		A6.1 Will your results warrant the level of mathematics used (i.e., will	
134		the end justify the means)?	38
135	A7	Is/are there an/_ alternative way/s to get to the same solution/s?	38
136		A7.1 Can you come up with illustrating examples, or even better, counter	
137		examples to your proposed solution/s?	38
138		A7.2 Is there an approximation that can arrive at the essentially the same	
139		proposed solution/s more easily?	39
140	A8	If you were the examiner of your proposal, how would you present the	
141		proposal in another way?	39
142		A8.1 What are the weaknesses of your proposal?	39
143	Append	ix B USAGE EXAMPLES	41
144	B1	Equations	42
145	B2	Notations	44
146	В3	Abbreviation	50
147	В4	Glossary	52
148	В5	Figure	53
149	В6	Table	59
150	В7	Algorithm or Pseudocode Listing	63
151	В8	Program/Code Listing	65
152	В9	Referencing	67
153		B9.1 A subsection	68
154		B9.1.1 A sub-subsection	69
155	B10	Index	70
156	B11	Adding Relevant PDF Pages (e.g. Standards, Datasheets, Specification	
157		Sheets, Application Notes, etc.)	71
158	Append	ix C PUBLICATION LIST AND AWARD	75
150			77
159	Append	ix D VITA	77
160	Index		79



LIST OF FIGURES

161

162

3.1	A quadrilateral image example	14
B.1	A quadrilateral image example	53
B.2	Figures on top of each other. See List. B.6 for the corresponding LaTeX code.	55
B.3	Four figures in each corner. See List. B.7 for the corresponding LaTeX code	57



100	I IS	$T \cap F$	FTAE	≀I FS
166		\mathbf{I}	I / \	

B.1	Feasible triples for highly variable grid	59
B.2	Calculation of $y = x^n$	63



ABBREVIATIONS

170	AC	Alternating Current	50
	CSS	Cascading Style Sheet	
172	HTML	Hyper-text Markup Language	50
173	XML		



NOTATION

175	$ \mathcal{S} $	the number of elements in the set S	52
176	Ø	the set with no elements	52
177	$h\left(t\right)$	impulse response	42
178	$\mathcal{S}^{(i)}$	a collection of distinct objects	
179	\mathcal{U}	the set containing everything	52
180	x(t)	input signal represented in the time domain	
181	y(t)	output signal represented in the time domain	
182	Through	out this thesis, mathematical notations conform to ISO 80000	-2 standard, e.g

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



188 GLOSSARY

189



LISTINGS

191	B.1	Sample LATEX code for equations and notations usage	43
192	B.2	Sample LATEX code for notations usage	47
193	B.3	Sample LaTeX code for abbreviations usage	51
194	B.4	Sample LaTeX code for glossary and notations usage	52
195	B.5	Sample LaTeX code for a single figure	54
196	B.6	Sample LaTeX code for three figures on top of each other	56
197	B.7	Sample LaTeX code for the four figures	58
198	B.8	Sample LaTeX code for making typical table environment	61
199	B.9	Sample LaTeX code for algorithm or pseudocode listing usage	64
200	B.10	Computing Fibonacci numbers	65
201	B.11	Sample LaTeX code for program listing	66
202		Sample LaTeX code for referencing sections	67
203	B.13	Sample LaTeX code for referencing subsections	68
204	B.14	Sample LATEX code for referencing sub-subsections	69
205	B.15	Sample LaTEX code for Index usage	70
206		Sample LaTeX code for including PDF pages	71



Chapter 1

INTRODUCTION

Contents

1.1	Background of the Study	2
1.2	Prior Studies	4
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	Overview	6



1.1 Background of the Study

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1.2 Prior Studies

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1.3 Problem Statement



1.4 Objectives

1.4.1 General Objective(s)

To ...;

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1.4.2 Specific Objectives

293 1. To ...;

294 2. To ...;

3. To ...;

296 4. To ...;

5. To ...;

1.5 Significance of the Study



1.6 Assumptions, Scope and Delimitations

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

1.7 Description and Methodology

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1.8 Overview

Provide here a brief summary and what the reader should expect from each succeeding chapter. Show how each chapter are connected with each other.

	De La Salle University	
324	Chapter 2	
325	LITERATURE REVIEW	
326	Contents	
327 328 329	2.1 Summary	



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

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			2. Literature Review	
		De La Salle Univer	sity	
377	2.1	Summary		
			10	

	De La Salle University	
378	Chapter 3	
379	THEORETICAL CONSIDERATIONS	
380	Contents	
381 382 383	3.1 Summary	



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3.1 Summary

Fig. 3.1 A quadrilateral image example.

	De La Salle University
430	Chapter 4
431	DESIGN CONSIDERATIONS
432	Contents
433 434 435	4.1 Summary



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4.1 Summary

Da	Τ.	C - 11	. T	T	ersity
De	La	San	eL	mve	ersity
					J

482	Chapter 5
483	METHODOLOGY

Contents

5.1	Implementation	19
5.2	Evaluation	21
5.3	Summary	23



5.1 Implementation

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		5. Methodology	
		De La Salle University	
582	5.3	Summary	
		23	

	De La Salle University
583	Chapter 6
584	RESULTS AND DISCUSSION
585 586	Contents

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Summary 6.1

613

614

616

617

618

619

620

621

622

623

624

625

626

627

628

629

630

631

632

633

634

	NS,
AND FUTURE DIRECTIVES	
Contents	
7.1 Concluding Remarks7.2 Contributions7.3 Recommendations7.4 Future Prospects	



7.1 Concluding Remarks

In this Thesis, ...

7.2 Contributions

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

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- 651 the ;
- 652 the ;

7.3 Recommendations

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7.4 Future Prospects

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

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- 2. the
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Produced: May 29, 2016, 23:47



Appendix A ANSWERS TO QUESTIONS TO THIS THESIS

Contents

A 1	How important is the problem to practice?	33		
A2	How will you know if the solution/s that you will achieve would be better			
	than existing ones?	33		
	A2.1 How will you measure the improvement/s?	33		
	A2.1.1 What is/are your basis/bases for the improvement/s?	34		
	A2.1.2 Why did you choose that/those basis/bases?	34		
	A2.1.3 How significant are your measure/s of the improvement/s'	? 34		
A3	What is the difference of the solution/s from existing ones?	35		
	A3.1 How is it different from previous and existing ones?	35		
A4	What are the assumptions made (that are behind for your proposed solution			
	to work)?	35		
	A4.1 Will your proposed solution/s be sensitive to these assumptions? .	36		
	A4.2 Can your proposed solution/s be applied to more general cases			
	when some of the assumptions are eliminated? If so, how?	36		
A5	What is the necessity of your approach / proposed solution/s?	36		
	A5.1 What will be the limits of applicability of your proposed solution/s?	37		
	A5.2 What will be the message of the proposed solution to technical			
	people? How about to non-technical managers and business men?	37		
A6	How will you know if your proposed solution/s is/are correct?	37		
	A6.1 Will your results warrant the level of mathematics used (i.e., will			
	the end justify the means)?	38		
A7	Is/are there an/_ alternative way/s to get to the same solution/s?	38		
	A7.1 Can you come up with illustrating examples, or even better, counter			
	examples to your proposed solution/s?	38		
	A7.2 Is there an approximation that can arrive at the essentially the same			
	proposed solution/s more easily?	39		
A8	If you were the examiner of your proposal, how would you present the			
	proposal in another way?	39		
	A8.1 What are the weaknesses of your proposal?	39		



A1 How important is the problem to practice?

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

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



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

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

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

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



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

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

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

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

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



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

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

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

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

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

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



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

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

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

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

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

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

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



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

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

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

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

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

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

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



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

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

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

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

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

A8.1 What are the weaknesses of your proposal?

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



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

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972 973	Appendix B USAGE EXAMPLES	
	41	



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

B1 Equations

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

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

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

Other example equations are as follows.

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

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

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



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

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

```
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) \
       \label{eq:conv}
8
    \end{eqnarray}
    Other example equations are as follows.
10
11
12
    \begin{eqnarray}
       \left[ \dfrac{ V_{1} }{ I_{1} } \right] =
13
14
       \begin{bmatrix}
15
          A & B \\
16
          C & D
       \end{bmatrix}
17
18
       \label{left} $$ \left[ \dfrac{ V_{2} }{ I_{2} } \right] \right] $$ \left[ \dfrac{ V_{2} }{ I_{2} } \right] $$
19
       \label{eq:ABCD}
20
    \end{eqnarray}
21
22
    \begin{eqnarray}
23
    {1\over 2} < \left( \int_{\infty} \mathbf{y} \right) 
        right\rfloor 2^{-17 \lfloor x \rfloor - \mathrm{mod}(\lfloor y\
        rfloor, 17)},2\right)\right\rfloor,
    \end{eqnarray}
24
25
26
    \begin{eqnarray}
27
    | \text{zeta(x)^3} \text{zeta(x+iy)^4} \text{zeta(x+2iy)} | =
   \ensuremath{\mbox{ \ exp\sum_{n,p}\frac{3+4\cos(ny\log p) +\cos (2ny\log p)}{np^{nx}}\ge 1}
28
    \end{eqnarray}
```



988 B2 Notations

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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 <code>isomath-test.tex</code>.

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.

 $\begin{array}{ll} \text{mathnormal} & A,B,\Gamma,\Delta,\Theta,\Lambda,\Xi,\Pi,\Sigma,\Phi,\Psi,\Omega,\alpha,\beta,\pi,\nu,\omega,v,w,0,1,9\\ \text{mathit} & A,B,\Gamma,\Delta,\Theta,\Lambda,\Xi,\Pi,\Sigma,\Phi,\Psi,\Omega,f\!f,f\!i,\beta,\ °,!,v,w,0,1,9\\ \text{mathrm} & A,B,\Gamma,\Delta,\Theta,\Lambda,\Xi,\Pi,\Sigma,\Phi,\Psi,\Omega,f\!f,f\!i,\beta,\ °,!,v,w,0,1,9\\ \text{mathbf} & \mathbf{A},\mathbf{B},\mathbf{\Gamma},\Delta,\Theta,\Lambda,\Xi,\Pi,\Sigma,\Phi,\Psi,\Omega,f\!f,f\!i,\beta,\ °,!,v,w,0,1,9\\ \text{mathsf} & A,B,\Gamma,\Delta,\Theta,\Lambda,\Xi,\Pi,\Sigma,\Phi,\Psi,\Omega,f\!f,f\!i,\beta,\ °,!,v,w,0,1,9\\ \text{mathtt} & A,B,\Gamma,\Delta,\Theta,\Lambda,\Xi,\Pi,\Sigma,\Phi,\Psi,\Omega,\uparrow,\downarrow,\beta,\ °,!,v,w,0,1,9 \end{array}$

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

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

Do the math alphabets match?

 $axlpha\omega axlpha\omega$ ax $lpha\omega$ $TC\Theta\Gamma TC\Theta\Gamma$

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: $\Lambda = E \cdot A$.

¹However, 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.



1002 Tensor symbols

1003

1004

Symbols for tensors are sans-serif bold italic,

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

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

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



1005 **Bold math version**

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

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

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

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

mathsf $A, B, \Gamma, \Delta, \Theta, \Lambda, \Xi, \Pi, \Sigma, \Phi, \Psi, \Omega, ff, fi, B, ^{\circ}, !, v, w, 0, 1, 9$

mathtt A, B, Γ , Δ , Θ , Λ , Ξ , Π , Σ , Φ , Ψ , Ω , \uparrow , \downarrow , \mathfrak{B} , $^{\circ}$, !, v, w, 0, 1, 9

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

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

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

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

Do the math alphabets match?

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

Vector symbols

1008

1009

1010

1013

1014

1015

1017

1018

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: $\Lambda = E \cdot A$.

Tensor symbols

1016 Symbols for tensors are sans-serif bold italic,

$$lpha = e \cdot a \iff lpha_{ijl} = e_{ijk} \cdot a_{kl}.$$

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

$$D = \epsilon_0 \epsilon_r E$$

 2 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.



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

Listing B.2: Sample LATEX code for notations usage

```
1020
           % A teststring with Latin and Greek letters::
1021
1022
           \newcommand{\teststring}{%
1023
           % capital Latin letters
           % A,B,C,
1024
        4
        5
1025
           A,B,
           % capital Greek letters
1026
        6
1027
           %\Gamma, \Delta, \Theta, \Lambda, \Xi, \Pi, \Sigma, \Upsilon, \Phi, \Psi,
1028
           \Gamma,\Delta,\Theta,\Lambda,\Xi,\Pi,\Sigma,\Phi,\Psi,\Omega,
        9
1029
           % small Greek letters
1030
       10
           \alpha,\beta,\pi,\nu,\omega,
1031
           \% small Latin letters:
       11
1032
       12
           % compare \nu, \nu, \nu, and \nu
1033
       13
1034
       14
           % digits
1035
       15
           0,1,9
1036
       16
1037
       17
1038
       18
1039
       19
           \subsection * { Math alphabets }
1040
       20
1041
       21
           If there are other symbols in place of Greek letters in a math
1042
       22
           alphabet, it uses T1 or OT1 font encoding instead of OML.
1043
       23
1044
       24
           \begin{eqnarray*}
           \mbox{mathnormal} & & \teststring \\
1045
       25
           \mbox{mathit} & & \mathit{\teststring}\\
1046
1047
       27
           \mbox{mathrm} & & \mathrm{\teststring}\\
1048
       28
           \mbox{mathsf} & & \mathsf{\teststring}\\
mbox{mathtt} & & \mathtt{\teststring}
1049
       29
1050
       30
1051
       31
           \end{eqnarray*}
1052
            New alphabets bold-italic, sans-serif-italic, and sans-serif-bold-
       32
1053
                italic.
1054
           \begin{eqnarray*}
1055
       34
           \mbox{mathbfit}
                                 & & \mathbfit{\teststring}\\
       35
1056
           \mbox{mathsfit}
                                 & & \mathsfit{\teststring}\\
1057
       36
           \mbox{mathsfbfit} & & \mathsfbfit{\teststring}
1058
       37
           \end{eqnarray*}
1059
       38
       39
1060
           Do the math alphabets match?
1061
       40
1062
       41
1063
           \mathnormal {a x \alpha \omega}
1064
       43
           \mathbfit
                          {a x \alpha \omega}
1065
       44
           \mathsfbfit{a x \alpha \omega}
1066
       45
           \quad
1067
       46
           \mathsfbfit{T C \Theta \Gamma}
1068
       47
           \mathbfit
                          {T C \Theta \Gamma}
                         {T C \Theta \Gamma}
1069
       48
           \mathnormal
1070
       49
1071
       50
1072
       51
           \subsection*{Vector symbols}
1073
       52
```

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```
1074
           Alphabetic symbols for vectors are boldface italic,
1075
           1076
       55
           while numeric ones (e.g. the zero vector) are bold upright,
           vec{a} + vec{0} = vec{a}.
1077
       56
1078
       57
1079
           \subsection *{Matrix symbols}
1080
       59
       60
1081
           Symbols for matrices are boldface italic, too: %
1082
       61
           \footnote{However, matrix symbols are usually capital letters whereas
1083
               vectors
1084
           are small ones. Exceptions are physical quantities like the force
1085
       63
           vector $\vec{F}$ or the electrical field $\vec{E}$.%
1086
       64
1087
       65
           $\matrixsym{\Lambda}=\matrixsym{E}\cdot\matrixsym{A}.$
1088
1089
       67
1090
       68
           \subsection*{Tensor symbols}
1091
       69
1092
       70
           Symbols for tensors are sans-serif bold italic,
1093
       71
1094
       72
           \[
1095
               \tensorsym{\alpha} = \tensorsym{e}\cdot\tensorsym{a}
       73
1096
       74
               \quad \Longleftrightarrow \quad
1097
       75
               \alpha_{ijl} = e_{ijk} \cdot a_{kl}.
           \]
1098
       76
1099
       77
1100
       78
1101
       79
           The permittivity tensor describes the coupling of electric field and
1102
       80
           displacement: \[
           \label{lem:constraint} $$\operatorname{D}=\operatorname{O}\times _{0}\times _{0}\times _{0}. $$
1103
       81
1104
       82
1105
       83
1106
       84
1107
       85
           \newpage
1108
       86
           \subsection * { Bold math version }
1109
       87
           The ''bold'' math version is selected with the commands
1110
       88
1111
       89
           \verb+\boldmath+ or \verb+\mathversion{bold}+
1112
       90
1113
       91
           {\boldmath
1114
       92
               \begin{eqnarray*}
1115
       93
               \mbox{mathnormal} & & \teststring \\
               \mbox{mathit} & & \mathit{\teststring}\\
1116
       94
1117
       95
               \mbox{mathrm} & & \mathrm{\teststring}\\
               \mbox{mathbf} & & \mathbf{\teststring}\\
mbox{mathsf} & & \mathsf{\teststring}\\
1118
       96
1119
       97
1120
       98
               \mbox{mathtt} &
                                & \mathtt{\teststring}
1121
       99
               \end{eqnarray*}
1122
      100
                New alphabets bold-italic, sans-serif-italic, and sans-serif-bold-
1123
                    italic.
1124
      101
               \begin{eqnarray*}
                                      & \mathbfit{\teststring}\\
1125
      102
               \mbox{mathbfit}
                                    &
1126
      103
               \mbox{mathsfit}
                                    & & \mathsfit{\teststring}\\
1127
      104
               \mbox{mathsfbfit} & & \mathsfbfit{\teststring}
1128
      105
               \end{eqnarray*}
1129
      106
1130
      107
               Do the math alphabets match?
```

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```
108
1131
1132
      109
              \mathnormal {a x \alpha \omega}
1133
      110
                            {a x \alpha \omega}
1134
      111
              \mathbfit
1135
              \mathsfbfit{a x \alpha \omega}
      112
1136
      113
              \quad
              \mathsfbfit{T C \Theta \Gamma}
1137
      114
                            {T C \Theta \Gamma}
1138
      115
              \mathbfit
1139
      116
              \mathnormal {T C \Theta \Gamma}
1140
      117
1141
      118
1142
      119
              \subsection*{Vector symbols}
1143
      120
1144
      121
              Alphabetic symbols for vectors are boldface italic,
1145
      122
              \ \ \vec{\lambda} = \vec{e}_{1} \cdot\vec{a}$,
1146
      123
              while numeric ones (e.g. the zero vector) are bold upright,
1147
      124
              \ \ \vec{a} + \vec{0} = \vec{a}$.
1148
      125
1149
      126
1150
      127
1151
      128
1152
              \subsection *{Matrix symbols}
      129
1153
      130
1154
      131
              Symbols for matrices are boldface italic, too: %
      132
1155
              \footnote{However, matrix symbols are usually capital letters whereas
1156
1157
      133
              are small ones. Exceptions are physical quantities like the force
1158
      134
              vector $\vec{F}$ or the electrical field $\vec{E}$.%
1159
      135
1160
      136
              $\matrixsym{\Lambda}=\matrixsym{E}\cdot\matrixsym{A}.$
      137
1161
1162
      138
1163
      139
              \subsection*{Tensor symbols}
1164
      140
1165
      141
              Symbols for tensors are sans-serif bold italic,
1166
      142
1167
      143
              1 [
                   \tensorsym{\alpha} = \tensorsym{e}\cdot\tensorsym{a}
1168
      144
1169
      145
                   \quad \Longleftrightarrow \quad
1170
      146
                   \alpha_{ijl} = e_{ijk} \cdot a_{kl}.
1171
      147
1172
      148
      149
              The permittivity tensor describes the coupling of electric field and
1173
      150
1174
              displacement: \[
1175
      151
              \c {D}=\ensuremath{\c D}=\ensuremath{\c C}\
      152
1179
```



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).



1207

1208

• Provide your own link text: style sheet.

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

Listing B.3: Sample LATEX code for abbreviations usage

```
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
      difference): \gls{html}. Here are some more entries:
   \begin{itemize}
5
      \item \acr{xml} and \acr{css}.
7
      \item Next use: \acr{xml} and \acr{css}.
8
      \item Full form: \gls{xml} and \gls{css}.
9
10
      \item Reset again. \glsresetall{abbreviation}
11
12
      \item Start with a capital. \Acr{html}.
13
14
15
      \item Next: \Acr{html}. Full: \Gls{html}.
16
      \item Prefer capitals? \renewcommand{\acronymfont}[1]{\
17
         MakeTextUppercase{#1}} \Acr{xml}. Next: \acr{xml}. Full: \gls{xml}
18
      \item Prefer small-caps? \renewcommand {\acronymfont}[1] {\textsc{#1}}
19
         \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
      \item Next use: \Acr{html}, \acr{xml} and \acr{css}.
27
28
      \item Full form: \Gls{html}, \gls{xml} and \gls{css}.
29
      \item Provide your own link text: \glslink{[textbf]css}{style}
31
32
   \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 <code>notation.tex</code> 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 <code>notation.tex</code>.

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

```
\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
      \item The universal set, denoted as \gls{not:universalSet}, is the
          set of everything.
8
      \item The empty set, denoted as \gls{not:emptySet}, contains no
9
          elements.
10
      \item The cardinality of a set, denoted as \gls{not:cardinality}, is
11
          the number of elements in the set.
12
   \end{enumerate}
```

1209

1210 1211 1212

1213 1214 1215

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1218

1219

1220

1221

1222



1223 B5 Figure

1224

1225

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



Fig. B.1 A quadrilateral image example.



1226 1227 Fig. B.1 is a gray box enclosed by a dark border. List. B.5 shows the corresponding LATEX code.

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

```
begin{figure}[!htbp]

centering

includegraphics[width=0.5\textwidth]{example}

caption{A quadrilateral image example.}

label{fig:example}

end{figure}

cleardoublepage

Fig.~\ref{fig:example} is a gray box enclosed by a dark border. List.~\

ref{lst:onefig} shows the corresponding \LaTeX \ code.

end{figure}
```





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



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





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

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

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Lorem ipsum dobr sit amet, consecteture adipiscing elit. Ut purus elit, vestillalum ut, placerat ar, adipiscing vitae, felis. Cumbirut dictum garida mauric.

Nam area luben, nomumuye equi, consecterat ili, vitapiata a magna. Donce
man and man a

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

Lorent jamm dohor ist anest, consectenture adjuscing elli. Ut purus elli, vestillalim ut a, placerat ac, adjuscing vitae, felis. Curabitur dictum gravida manuris.

(I) Nan accu libero, nomumury eget, consecterate ell, vidjentate a, magna. Dance
netture elli periodi pe

Lorem ipsum dober sit amet, consecteture aflipicing elit. Ut purus elit, vestibuhan ut, pheerat ac, dulpicing vitae, feits. Cumbitur datum gavela massis,
which is a consecutive and the consecutive and the consecutive velicities angue en unque. Pedestenegae habitam dunch tristique senectus et
netus et maleunada fanos ac turpio egotas. Mauris ut loo.

Lorem ipsum dober at marci consecutiver andipicing elit. Un purus elit, vestibuhan ut, pheerat ac, adipicing vitae, feit. Cumbitur dictum gaveita massis.

Nam arcu libera, nomumy egot, consecuteur al, vighuntae a, nagna. Done
vehicula aque en noque. Pedestenegae habitam modi tristique senectus et
netus et maleunada fanos ac turpio egotas. Mauris ut loo.

Lorem ipsum dober sit amet, consecuteur adapticing elit. Ut purus elit, vestibuhum ut, pheerat ac, adipicing vitae, feits. Cumbitur detung gaveita massis.

Nam arcu libera, nomumny egot, consecuteur al, vulputate a, nagna. Done
vehicula aque en unque. Pedestenegae habitam unde tristique senectius et
neste et maleunada fanos ac turpic egotas. Mauris ut lor.

**Lorem ipsum dober sit amet, consecuteur adipicing elit.

**Lorem ipsum dober sit amet, consecuteur adipicing elit.

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

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



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

```
\begin{figure}[!htbp]
   \centering
   \subbottom[A sub-figure in the upper-left corner.]{
   \includegraphics[width=0.45\textwidth]{example}
   \label{fig:upprleft}
   \subbottom[A sub-figure in the upper-right corner.]{
   \includegraphics[width=0.45\textwidth]{example}
10
   \label{fig:uppright}
11
12
   \vfill
   \subbottom[A sub-figure in the lower-left corner.]{
13
   \includegraphics[width=0.45\textwidth]{example}
   \label{fig:lowerleft}
15
16
17
   \hfill
   \subbottom[A sub-figure in the lower-right corner]{
18
   \includegraphics[width=0.45\textwidth]{example}
19
20
   \label{fig:lowright}
21
   \verb|\caption{Four figures in each corner. See List.~\ref{lst:fourfigs} for
       the corresponding \LaTeX \ code.}
   \label{fig:fourfig}
   \end{figure}
```



1229

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) (2, 2, 2745), (2, 3, 0), (3, 1, 0)
	(-,,,,	Continued on next page

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)

1230



List. B.8 shows the corresponding LATEX code.

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

```
1232
           \begin{center}
1233
        1
1234
        2
           {\scriptsize
1235
           \beta_{0.0} = \frac{1}{2}
1236
           \caption{Feasible triples for highly variable grid} \label{tab:triple_
1237
1238
               grid} \\
           \hline
1239
1240
           \hline
           \textbf{Time (s)} &
1241
        7
        8
           \textbf{Triple chosen} &
1242
1243
        9
           \textbf{Other feasible triples} \\
1244
       10
           \hline
1245
       11
           \endfirsthead
           \multicolumn{3}{c}%
1246
       12
1247
           {\textit{Continued from previous page}} \\
       13
1248
       14
           \hline
1249
       15
           \hline
1250
       16
           \textbf{Time (s)} &
1251
       17
           \textbf{Triple chosen} &
1252
       18
           \textbf{Other feasible triples} \\
1253
       19
           \hline
1254
       20
           \endhead
1255
       21
           \hline
1256
       22
           \multicolumn{3}{r}{\textit{Continued on next page}} \\
1257
       23
           \endfoot
1258
       24
           \hline
1259
       25
           \endlastfoot
1260
       26
           \hline
1261
       27
           0 & (1, 11, 13725) & (1, 12, 10980), (1, 13, 8235), (2, 2, 0), (3, 1, 0)
1262
       28
1263
           2745 & (1, 12, 10980) & (1, 13, 8235), (2, 2, 0), (2, 3, 0), (3, 1, 0)
1264
       29
1265
           5490 & (1, 12, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1266
1267
       31
           8235 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1,
1268
1269
       32
           10980 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1,
1270
               0) \\
1271
           13725 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 1)
                0) \\
1272
1273
           16470 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
       34
           19215 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1,
1274
1275
                0) \\
1276
           21960 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1,
                0) \\
1277
           24705 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1,
1278
       37
                0) \\
1279
           27450 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1,
1280
       38
                0) \\
1281
1282
       39
           30195 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
           32940 \& (1, 13, 16470) \& (2, 2, 2745), (2, 3, 0), (3, 1, 0) \setminus
1283
       40
1284
           35685 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1285
       42 | 38430 & (1, 13, 10980) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
```

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```
41175 & (1, 12, 13725) & (1, 13, 10980), (2, 2, 2745), (2, 3, 0), (3, 1,
1286
1287
            43920 & (1, 13, 10980) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1288
            46665 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
       45
1289
1290
            49410 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
       46
1291
            52155 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1,
1292
                 0) \\
       48
            54900 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1293
1294
        49
            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)
1295
       50
                                                                                //
            63135 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0)
1296
1297
        52
            65880 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0)
            68625 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
1298
       53
            71370 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1299
1300
           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) \\
1301
            79605 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1302
       57
           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,
1303
       58
1304
1305
           87840 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1306
           90585 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1307
       61
1308
           93330 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \
1309
           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) \\
1310
       64
            101565 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
       65
1311
1312
       66
            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) \\
1313
       67
1314
       68
            112545 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0),
1315
       69
               1, 0) \\
1316
            115290 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1317
1318
            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) \
1319
           123525 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
126270 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3,
1320
       73
1321
1322
               1, 0)
                      11
1323
            129015 &
                      (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
            131760 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
1324
1325
       77
            134505 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1326
       78
            137250 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1327
            139995 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
       80
            142740 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
1328
1329
       81
            145485 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3,
1330
           148230 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
150975 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1331
1332
       83
            153720 & (1, 12, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1333
1334
            156465 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1335
            159210 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1336
            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) \\
1337
1338
       89
            \end{tabularx}
1339
       90
           \end{center}
1349
```



B7 Algorithm or Pseudocode Listing

1343 1344 1345 Table B.2 shows an example pseudocode. Note that if the pseudocode exceeds one page, it can mean that its implementation is not modular. List. B.9 shows the corresponding LATEX code.

Table B.2 Calculation of $y = x^n$

Input(s):

 $\begin{array}{lll} n & & : & n \text{th power; } n \in \mathbb{Z}^+ \\ x & & : & \text{base value; } x \in \mathbb{R}^+ \end{array}$

Output(s):

y: result; $y \in \mathbb{R}^+$

Require: $n \ge 0 \lor x \ne 0$

Ensure: $y = x^n$

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



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

```
\begin{table}[!htbp]
  1
  2
                      \caption{Calculation of $y = x^n$}
  3
                      \label{tab:calcxn}
                      {\footnotesize
  4
                      \begin{tabular}{111}
  5
                      \hline
  7
                      \hline
                      {\bfseries Input(s):} & & \\
  8
  9
                      n & : & nth power; n \in \mathbb{Z}^{+}
10
                      x & : & base value; x \in \mathbb{R}^{+}
11
12
                      {\bfseries Output(s):} & & \\
                      y & : & result; y \in \mathbb{R}^{+} \\
13
14
                      \hline
15
                      \hline
16
17
                      \end{tabular}
18
19
                      \begin{algorithmic}[1]
20
                      {\normalfont} \{ \normalfont 
                                \REQUIRE $n \geq 0 \vee x \neq 0$
21
                                \ENSURE $y = x^n$
22
                               \STATE $y \Leftarrow 1$
23
                                \IF { n < 0 }
24
25
                                                     \STATE $X \Leftarrow 1 / x$
                                                     \STATE $N \Leftarrow -n$
26
27
                                \ELSE
28
                                                     \STATE $X \Leftarrow x$
29
                                                     \STATE $N \Leftarrow n$
                                \ENDIF
30
                                \WHILE{$N \neq 0$}
31
32
                                                     \IF{$N$ is even}
33
                                                                         \STATE $X \Leftarrow X \times X$
                                                                         \STATE $N \Leftarrow N / 2$
34
35
                                                     \ELSE[$N$ is odd]
36
                                                                         \STATE $y \Leftarrow y \times X$
37
                                                                         \STATE $N \Leftarrow N - 1$
38
                                                    \ENDIF
                                \ENDWHILE
39
40
41
                      \end{algorithmic}
            \end{table}
```



B8 Program/Code Listing

 List. B.10 is a program listing of a C code for computing Fibonacci numbers by calling the actual code. Please see the code subdirectory.

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

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



List. B.11 shows the corresponding LATEX code.

Listing B.11: Sample LaTeX code for program listing

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 Lagrangian that Lagrangian La

Listing B.12: Sample LaTeX code for referencing sections

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

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



B9.1 A subsection

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

Listing B.13: Sample LATEX code for referencing subsections

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

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



B9.1.1 A sub-subsection

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Referencing sub-subsections: This section is Sec. B9.1.1, which shows how to refer to a sub-subsection. List. B.14 shows the corresponding LATEX code.

Listing B.14: Sample LATEX code for referencing sub-subsections

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

Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Etiam lobortis facilisis sem. 1380 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec 1381 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus 1382 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor. 1383 Praesent in sapien. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Duis fringilla 1384 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue 1385 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris. 1386 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit 1387 amet ipsum. Nunc quis urna dictum turpis accumsan semper. 1388



1390 1391 1392 1393 1394 1395

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B10 Index

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

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

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

Listing B.15: Sample LaTeX code for Index usage

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



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1400

1401 1402

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

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

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

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



EXILINX.

UltraScale Architecture and Product Overview

Virtex UltraScale FPGA Feature Summary

Table 6: Virtex UltraScale FPGA Feature Summary

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

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

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



EXILINX.

UltraScale Architecture and Product Overview

Virtex UltraScale Device-Package Combinations and Maximum I/Os

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

	Package	VU065	VU080	VU095	VU125	VU160	VU190	VU440
Package ⁽¹⁾⁽²⁾⁽³⁾	Dimensions (mm)	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

- Go to Ordering Information for package designation details.
 All packages have 1.0mm ball pitch.
 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.

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EXILINX.

UltraScale Architecture and Product Overview

Virtex UltraScale+ FPGA Feature Summary

Table 8: Virtex UltraScale+ FPGA Feature Summary

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

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

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

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

- 1. Go to Ordering Information for package designation details.
- 2. All packages have 1.0mm ball pitch.
- 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.
 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.

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

10

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

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Appendix C PUBLICATION LIST AND AWARD

Journal

1409 1. ...

1406

1407

1410 2. ...

1411 Conference

1412 1. ...

1413 2. ...



1414	Others
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1415 1. ...

1416 2. ...

1417 Award

1418 1. ...

1419 2. ...



Appendix D VITA

Ryan Joshua Liwag is currently taking up his B.Sc. Computer Engineering studies and is in his 4th academic year. He has able to acquire skills in the field of Computer Engineering. He is also a member of the DLSU Eco Car Team. His interest in the field of Computer Engineering is focused more on the hardware side particularly circuit design, benchmarking and .

Anfernee Rapio is currently taking up his B.Sc. Computer Engineering studies and is in his 4th academic year. He has able to acquire skills in the field of Computer Engineering. His interest in the field of Computer Engineering is focused more on the programming side particularly C programming on microcontrollers.

 Lance Randall Eco is currently taking up his B.Sc. Computer Engineering studies and is in his 4th academic year. He has able to acquire skills in the



field of Computer Engineering. His interest in the field of Computer Engineering is focused more on the hardware side particularly circuit assembly and designing.

1439

Kevin Jeff Cepria is currently taking up his B.Sc. Computer Engineering studies and is in his 4th academic year. He has able to acquire skills in the field of Computer Engineering. He is also a member of the DLSU Eco Car Team. His interest in the field of Computer Engineering is focused more on the programming side particularly Android and software development.

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INDEX

1440	contributions,	28
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Fredholm integral, 70

summary, 4