CERTIFICATE

I, **OBAIDUR RAHMAN**, Roll No. 2K17/PSY/10 student of M. Tech. in POWER SYSTEMS, hereby declare that the dissertation/project titled "**MODELING, DESIGN AND ANALYSIS OF LED LIGHTING SYSTEMS FOR APPLICATIONS IN ILLUMINATION CONTROL AND HORTICULTURE**" under the supervision of **Dr. PRIYA MAHAJAN** of Electrical Engineering Department, Delhi Technological University in partial fulfillment of the requirement for the award of the degree of Master of Technology has not been submitted elsewhere for the award of any Degree.

Place: Delhi **(OBAIDUR RAHMAN)**

Date:

(Dr. PRIYA MAHAJAN)
PROFESSOR

ACKNOWLEDGEMENT

First and foremost, my utmost gratitude to **Dr. Priya Mahajan** Mam. She has been a great mentor without whom this work would not have been possible at all. She motivated me at times when it was much needed and corrected my mistakes many times so as to bring out the best in me and my work. She has always been available, whenever I sought out for help and has shown keen interest in guiding my work.

I am very grateful to my M.Tech. Coordinator **Prof. Rachana Garg** Mam for providing me with an environment to complete my work successfully and tipping me up with some expert suggestions whenever my work got stuck.

I would like to thank all the faculty members of department of Electrical engineering, DTU, Delhi for their constant encouragement.

I would like to thank **Mr. Parveen Mahajan** for providing me with his invaluable support and precious time. I thank him for all the help he gave whenever some important data was required for the work progress.

I would like to thank all my M.Tech colleagues and PhD scholars, specially Shirish Sir, Pallavi Mam and Avdhesh Sir for their constant guidance and help.

Last but not the least, I would like to thank my mom who has always been my backbone. I can't imagine doing something as significant as this work successfully without her support, wisdom and love.

OBAIDUR RAHMAN
2K17/PSY/10
M.TECH (POWER SYSTEMS)
DELHI TECHNOLOGICAL UNIVERSITY

ABSTRACT

LED is a light emitting semiconductor device which is nowadays, swiftly replacing conventional lighting system, owing to its high intensity and low energy consumption. In this work, LED lighting Systems have been used for controlling illumination level of a given closed space and another application of LED lighting systems for horticulture has also been carried out. In order to achieve the task, the modeling of LED is required. The very basic modeling of LED can be done by considering it as a resistor. But this has some serious limitations as the non linear I-V characteristics of the LED cannot be modeled using a resistor. To model the non linear IV characteristics of LED, some advanced modeling techniques viz. Piecewise Linear Approximation and Maclaurin series expansion based modeling have been taken up here.

For illumination control of given closed space, LED lights have been used as controlled light source and there is some illumination due to external light sources as well. To drive the LEDs, a driver is needed which provides a DC supply to it. In this work, AC supply has been used which is fed to a rectifier coupled with a buck converter to drive the LEDs with DC. Buck converter's switching is controlled using PWM technique. The microcontroller is given a set point which is compared to a feedback signal generated by LUX sensor. The error signal so generated is fed to a comparator unit to generate the PWM gate signal (amplified and isolated with the help of an optocoupler) which is then fed to the gate of the MOSFET switch of the buck converter. The hardware setup has been simulated first using MATLAB-Simulink and various important parameters such as THD have also been compared.

The application of LED lighting systems for Horticulture has unconventionally been approached by using RGB LEDs as opposed to the use of hyper red or deep blue LEDs. This has been done to take care of the micronutrient requirement of the crops. The data regarding the plant (S. Platenesis), that is, the wavelength or color of light required for the optimum growth has been known beforehand and using this, light of required color is produced by applying the method of color mixing using variable duty cycles for RGB lights.

CONTENTS

CERTIFICATE			ii
ACKNOWLEDGEMENT			iii
ABSTRACT			iv
CONTENTS			v
LIST OF FIGURES			viii
LIST OF TABLES			x
LIST OF ABBREVIATIONS AND SYMBOLS			xi
CHAPTER 1	**INTRODUCTION**		1-4
	1.1	General	1
	1.2	Motivation	2
	1.3	Problem Formulation	3
	1.4	Dissection of Thesis	4
	1.5	Conclusion	4
CHAPTER 2	**LITERATURE REVIEW**		5-9
	2.1	Introduction	5
	2.2	Modeling of LED in MATLAB and Simulink	5
	2.3	Automated control of illumination level using LEDs	6
	2.4	Application of LEDs in Horticulture	8
	2.5	Conclusion	9
CHAPTER 3	**MODELING OF IV CHARACTERISTIC OF LED**		10-19
	3.1	Introduction	10
	3.2	Modeling	12
		3.2.1 Modeling using Piecewise Linear Approximation	12
		3.2.2 Modeling using Maclaurin Series Expansion	13
	3.3	Implementation	15
		3.3.1 Calculation of parameters for PLA Model	15

3.3.2 Calculation of parameters for Maclaurin Series expansion based model 16
3.4 Conclusion 18

CHAPTER 4 ILLUMINATION CONTROL USING LED LIGHTING SYSTEM 20-35
4.1 Introduction 20
4.2 Modeling and Design of Automated Controlled LED Lighting System 22
4.2.1 Block Diagram of the Model 22
4.2.2 LED driver design 23
4.2.3 Control Circuit Design 26
4.3 Hardware Implementation 27
4.3.1 AC to DC conversion circuit 29
4.3.2 LED driver circuit design 30
4.3.3 Gate Driver (Control Circuit) 32
4.3.4 Sensing Circuit 34
4.3.5 Software (Arduino IDE) 35
4.4 Conclusion 35

CHAPTER 5 HORTICULTURE USING RGB LEDs 36-43
5.1 Introduction 36
5.2 Development of Simulink Model 37
5.2.1 Calculation of parameters 37
5.2.2 RGB LED driver 39
5.2.3 Color Mixing using Variable Dimming Scheme 41
5.3 Conclusion 43

CHAPTER 6 RESULTS AND DISCUSSIONS 44-55
6.1 Introduction 44
6.2 Modeling of IV characteristics of LED 44

6.3 Illumination control using LED lights 45
6.3.1 Simulation Results 45
6.3.2 Hardware Results 48
6.3.3 Comparison of THD values obtained from Circuit Simulation versus The Hardware 51
6.4 Horticulture using RGB LED Lights 53
6.5 Conclusion 55

CHAPTER 7 CONCLUSION AND SCOPE OF FUTURE WORK 56-58
7.1 Conclusion 56
7.2 Scope of Future Work 57

REFERENCES 59

APPENDIX 64

LIST OF PUBLICATIONS 72

LIST OF FIGURES

Figure 1.1	LED symbol and its 2 pin variant	1
Figure 1.2	Various applications of LEDs	2
Figure 3.1	LED symbol and its 2 pin variant	11
Figure 3.2	Approximate linear model.	11
Figure 3.3	Measured I-V curve of LED sample, LNL-190UW-4H	12
Figure 3.4	Generalized PLA model	13
Figure 3.5	Five branched PLA model.	13
Figure 3.6	Equivalent circuit for Maclaurin series based model.	15
Figure 3.7	I-V characteristics using PLA technique.	16
Figure 3.8	Section of LED I-V curve from datasheet locating key points	17
Figure 3.9	I-V characteristics using Maclaurin series expansion based modeling technique	18
Figure 4.1	Block Diagram of the model	22
Figure 4.2	Basic Buck converter scheme	25
Figure 4.3	Desired Illumination level to be achieved	26
Figure 4.4	Illumination level of room	26
Figure 4.5	LED intensity vs LED current	27
Figure 4.6	Complete circuit diagram of the proposed work	28
Figure 4.7	Rectifier circuit with dc voltage regulation	29
Figure 4.8	Internal circuit of IC A 6N137	33
Figure 4.9	Generation of PWM using Arduino UNO	33
Figure 4.10	Pin configuration of BH1750	34
Figure 5.1	Absorption Spectrum of various photosynthetic pigments	37
Figure 5.2	The connection scheme for each of the RGB LED array	39
Figure 5.3	Block diagram of the complete setup	41
Figure 5.4	The driving scheme for individual color arrays	41
Figure 5.5	The Color Mixing Chart	42
Figure 5.6	Chart depicting color, wavelength and the material of LED substrate	43

Figure 6.1	Comparison of Measured curve with Piecewise and Maclaurin model curve done in MATLAB 2016a.	45
Figure 6.2	Real time plot of LED current(amp) and LED voltage(volts)	46
Figure 6.3	Output from PI controller	46
Figure 6.4	Zoomed section of PWM signal generated by the PI controller	47
Figure 6.5	Voltage at the input of Buck converter	47
Figure 6.6	Plot of Achieved result against Desired Result	48
Figure 6.7	The complete Setup	48
Figure 6.8	PWM wave generated by arduino	49
Figure 6.9	Inverted output from IC A6N137	49
Figure 6.10	PWM output from arduino v/s Inverted output from A6N137	50
Figure 6.11	Serial monitor displaying the ambient light intensity readings	50
Figure 6.12	THDi values measured on FLUKE view 2 Scopemeter	52
Figure 6.13	Current requirement of hyper red LED per day	53
Figure 6.14	Current requirement of green LED per day	53
Figure 6.15	Current requirement of deep blue LED per day	53
Figure 6.16	Current vs Time curve for hyper red LED	54
Figure 6.17	Current vs Time curve for green LED	54
Figure 6.18	Current vs Time curve for deep blue LED	55

LIST OF TABLES

TABLE I Various parameters of Shockley's Equation	14
TABLE II Parameters For Piecewise Model	16
TABLE III Parameters For Maclaurin Model	18
TABLE IV Some Important Parameters	25
TABLE V Data for Inductor Design	30
TABLE VI I-V Data For RGB Lights	38
TABLE VII Comparison of THDi Values	52
TABLE VIII Color Requirement Chart (Assumed)	54

LIST OF ABBREVIATIONS AND SYMBOLS

LED	Light emitting diode
IV	Current-Voltage
PLA	Piecewise Linear Approximation
RGB	Red Green Blue
PWM	Pulse Width Modulation
MOSFET	Metal Oxide Semiconductor Field Effect Transistor
THD_v	Total Harmonic Distortion in voltage
THD_i	Total Harmonic Distortion in current
AC-DC	Alternating Current-Direct Current
CFL	Compact Fluorescent Lamps
RMS	Root Mean Square
VDS	Variable Dimming Scheme
V_F	Voltage Drop across the LED
I_{LED}	Current passing through the LED
I_{SAT}	Saturation current of LED
η	Ideality factor
q	Magnitude of the Electronic Charge (1.602×10^{-19} C)
k	Boltzmann's constant (1.38×10^{-23} J/K)
T	Absolute temperature ($273 + T_a$) in Kelvin
V_{in}	Typical input voltage of Buck converter
V_{out}	Desired output voltage of Buck Converter
f_s	Minimum switching frequency of the converter
ΔI_L	Estimated inductor ripple current
L_c	Critical value of Inductance
C_c	Criticalvalue of Capacitance
α	Duty Cycle