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M. Sc. Thesis – Electrical Electronics Engineering

İPEK İNAL

UNIVERSITY OF GAZİANTEP
GRADUATE SCHOOL OF
NATURAL & APPLIED SCIENCES

OPTIMIZATION OF ILLUMINATION YIELDS OF BUCK-BASED POWER LED DRIVERS

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Optimization of Illumination Yields of Buck-Based Power LED Drivers

M.Sc. Thesis
İn
Electrical and Electronics Engineering
University of Gaziantep

Supervisor
Prof. Dr. Ö. Faruk FARSAKOĞLU

Co Supervisor
Prof. Dr. Arif NACAROĞLU

by
İpek İNAL
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Prof. Dr. Ramazan Koç
Director

I certify that this thesis satisfies all the requirements as a thesis for the degree of Master of Science.

Prof. Dr. Celal Koraşlı
Head of Department

This is to certify that we have read this thesis and that in our opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

Prof. Dr. Arif Nacaroğlu
Co Supervisor

Prof. Dr. Ö. Faruk Farsakoğlu
Supervisor

Examining Committee Members | Signature

1.Prof. Dr. Ö. Faruk FARSAKOĞLU ....
2.Doç. Dr. Nuran DOĞRU ....
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İpek İNAL

ABSTRACT

OPTIMIZATION OF ILLUMINATION YIELDS OF BUCK-BASED POWER LED DRIVERS

İNAL, İpek
M.Sc. in Electrical and Electronics Eng.
Supervisor: Prof. Dr. Ö. Faruk FARSAKOĞLU
Co Supervisor: Prof. Dr. Arif NACAROĞLU
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Luminous power LED technology has been improving quite fast. This technology will replace completely lighting components that are used currently in the next decade due to its lighting advantages. In this study, current and voltage-limiting driver circuit designs were examined. The current-limiting driver circuit design has been selected to be applicable in terms of power LED's structure. In this case, current-limiting driver circuit designs were carried out. The buck-based type LED driver was selected considering the number of power LED units among the driver types; buck-based, boost-based, and buck-boost-based. In the phase of designing at first step, the buck-based circuit, power LEDs were driven with calculated resistor value. In the second step, the driver circuit design with linear regulator was made to drive power LEDs. In the last step the driver circuit with switching regulator was designed. Power LED driver circuits were designed, with the input voltage and component parameters at which output efficiencies were maximum. Then, the power LED driver circuits were designed, and circuit output efficiency value measurements were made without using cooling unit. The effects of cooling units on output efficiency values were examined. As a result, different driver circuit designs and efficiency comparisons were made. At maximum output illumination efficiency, the power LED driver circuit design was carried out with the precision of 10^{-4}.

Keywords: Power LED driver, illumination yield, buck-boost components, circuit efficiency

ÖZET

BUCK TABANLI GÜÇ LED SÜRÜCÜLERİNİN AYDINLANMA VERİMLİLİKLERİNİN OPTİMİZASYONU

İNAL, İpek
Yüksek Lisans Tezi, Elektrik ve Elektronik Müh.
Tez Yöneticisi: Prof. Dr. Ö. Faruk FARSAKOĞLU
Tez Ortak Yöneticisi Prof. Dr. Arif NACAROĞLU
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Güç LED aydınlatma teknolojisi oldukça hızlı gelişmeye devam etmektedir. Bu teknoloji aydınlatma avantajlarından dolayı önümüzdeki on yılda günümüzde kullanılan aydınlatma elemanlarının yerini tamamen alacaktır. Bu çalışmada akım ve voltaj sınırlamalı sürücü devre tasarımları incelenmiştir. LED'in yapısına uygun olması bakımından akım sınırlamalı sürücü devre tasarımı seçilmiştir. Bu amaçla akım sınırlamalı sürücü devre tasarımı yapılmıştır. Tasarımı yapılan sürücü devrelerde LED adeti bakımından düşürücü, yükseltici, düşürücü-yükseltici tiplerinden düşürücü tipi tercih edilmiştir. Düşürücü sürücü devre tasarımında LED'ler öncelikle değeri belirlenen direnç ile sürülmüştür. İkinci aşamada LED'leri sürmek için doğrusal regülâtörlü sürücü devre tasarımı yapılmıştır. Son aşamada ise anahtarlamalı sürücü devre tasarımı yapılmıştır. Çıkış aydınlatma verimini maksimum yapacak sürücü devre eleman değerleri hesaplanmıştır. Güç LED sürücü devre tasarımı yapıldıktan sonra devre çıkış verim değeri ölçümleri soğutucu eleman olmadan yapılmıştır. Soğutucu elemanın çıkış aydınlanma verim üzerine olan etkisi incelenmiştir. Sonuç olarak, farklı sürücü devre tasarımları ve verim karşılaştırmaları yapılmıştır. Maksimum verimlilikte power LED sürücü devre tasarımı 10^{-4} verim hassasiyeti ile gerçekleştirilmiştir.

Anahtar Kelimeler: Güç LED sürücü, aydınlanma verimi, düşürücü-yükseltici elemanlar, devre verimliliği

To my mother Atiye İNAL and my father Ali Yaşar İNAL

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CONTENTS

Page

LIST OF FIGURES

Page

LIST OF TABLES

Page

NOMENCLATURE

Ø	Luminous Flux (lm)
ß	Spatial Angel
I	Luminous Intensity (I= Ø/ß)
S	Surface Area
E	Illuminance (E= Ø/S)
Lx	Lux
L	Luminance
EMC	Electro - Magnetic Compatibility
EMI	Electro - Magnetic Interference
Ct	Timing Capasitor
D	Diyot
f	Frequency
cd	Candela
CFL	Compact Fluorescents
lm	Lumen
W	Watt
P	Power
V	Voltage
K	Room Index
N	Number of Fitting
Hm	Mounting Height
E	Lux Level
A	Room Area
Φ	Flux

m_e	Electron Mass
m_h	Hole Mass
V_f	Threshold Voltage
V_p	Input Voltage
P_R	Resistor Power
P_{out}	Output Power
P_{total}	Total Power
mA	Miliampere
^0C	Degree Centigrade
C	Capasitance
Q	Transistor
V_{sat}	Saturation Voltage
V_{out}	Output Voltage
V_{in}	Input Voltage
I_{pk}	Switch Current
C_o	Filter Capasitor
V_{ripple}	Ripple Voltage
I_{out}	Output Current
$P_{ind, winding}$	Inductor Winding Power Loss
$P_{switch, cond}$	Conduction Power Loss in Swicth
$P_{diode, cond}$	Conduction Power Loss in Diode
$P_{sensing, res}$	Conduction Power Loss in Sensing resistor
P_{static}	Static Power Loss
$P_{swicth, sw}$	Switching Power Loss
P_{core}	Core Power Loss in Inductor
$P_{loss, total}$	Total Power Loss
Ω	Ohm
nm	Nanometer

CHAPTER 1

INTRODUCTION

Power LED lighting technology is progressing fast due to its technical and economical advantages. The circuit design the driver for power LED lighting is of important. In the case of designing driver circuits light output efficiencies could be compared with each other.

In this study, current and voltage-limiting driver circuit designs were examined. Current-limiting driver circuit design was selected to be suitable in terms of the power LED's structure and then, it has been studied on the light output efficiencies of different driver circuits. The buck-based type LED driver was selected considering the number of power LED units among the driver types; buck-based, boost-based, and buck-boost-based. As designing the buck-based circuit, power LED's was driven with determined resistor value at the first step. According to increasing input voltage values, the resistor value that needs to be connected to power LEDs in series were calculated. The power values that were used on the driver circuit and circuit light output efficiencies were calculated. Then, driver circuit was designed with the input voltage and component parameters at which circuit output illumination efficiency was maximum. At the computations, the circuit design program, Proteus was used. In the experimental studies, measurements were made without using cooling device. Subsequently, the experiments were carried out by using cooling unit in order to determine the effect of cooling unit on the output efficiency.

In the second step, a circuit design with linear regulator was made to drive power LEDs. The calculations of component parameters that need to be used in circuit were made according to increased input voltage values. Output efficiency values were calculated for each case. Then, the circuit was designed with the input voltage and component parameters at which circuit output efficiency was maximum. In the experimental studies, measurements were made without using cooling device.

Subsequently the experiments were carried out by using cooling unit in order to determine the effect of cooling unit on the output efficiency. In the last, step the driver circuit with switching was designed. The power values that were spent on circuit depending on different frequency values were calculated. The frequency at which the circuit output efficiency was highest was taken as basis. At the frequency value taken as basis; the component parameter calculations that need to be used in the increasing input voltage were made, and power values that were spent on the circuit were calculated. Output efficiency values were calculated for each case. After the circuit was designed with the input voltage and component values at which circuit output efficiency was at maximum In the experimental studies, measurements were made without using cooling device. Subsequently the experiments were carried out by using cooling unit in order to determine the effect of cooling unit on the output efficiency.

Thus, different driver circuit designs and efficiency comparisons have been achieved. The relationship between the cooling unit and the circuit output efficiency was examined. At maximum efficiency, power LED driver circuit design has been carried out with the precision of 10^{-4}.

1.1 Light

Light is simply a name for a range of electromagnetic radiation that can be detected by the human eye. Electromagnetic radiation has a dual nature as both particles and waves. The "electromagnetic spectrum" is simply a phrase used to describe electromagnetic radiation of all wavelengths. This includes radio waves, microwaves, infrared, visible light, ultraviolet, x rays, gamma rays, and other electromagnetic radiation of longer and shorter wavelengths [1].

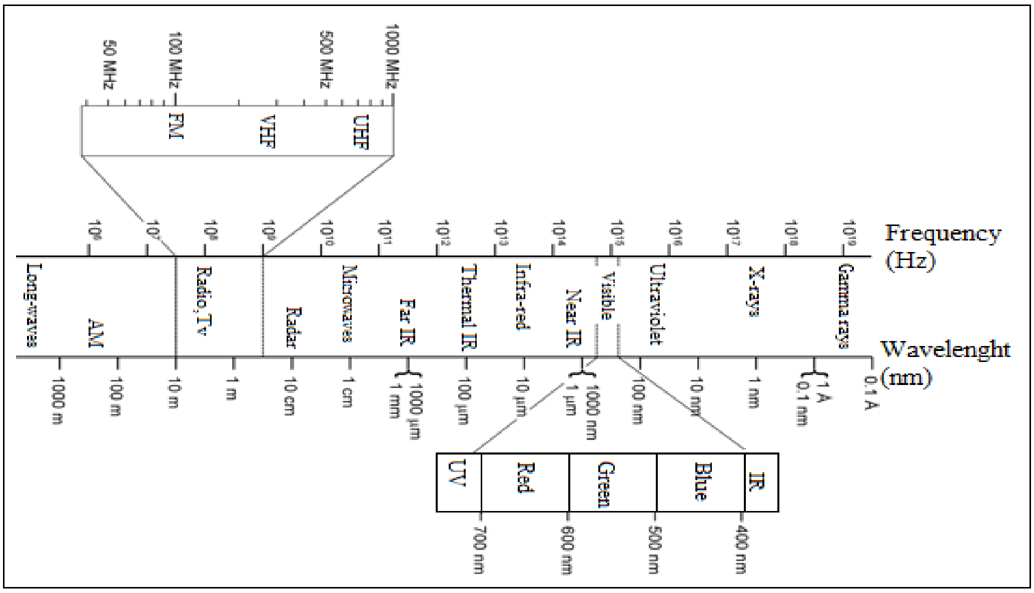


Figure 1.1 Complete electromagnetic spectrum and visible region.

1.2 Illumination

The illumination of a surface is proportional to the intensity of the source of light producing it, and it varies inversely as the square of the distance between the source and the illuminated surface. The unit of illumination is the lux. In examining terminology for illumination, it is useful to separate the spatial considerations from the spectral concerns [2]. In other cases, the spatial and spectral issues can not be separated physically, but it is useful to separate them conceptually. The commonly used spatial quantities are flux, irradiance, intensity, and radiance. Flux Φ, is the optical power or rate of flow of radiant energy.

1.2. a Illumination Spatial Quantities

Irradiance E, is the flux per unit area striking a surface. Occasionally, the flux per unit area leaving a surface, called exitance, M, is important. However, the geometry is the same as for irradiance, so it will not be treated separately here. Furthermore, when exitance is used, it is often the flux leaving a nonphysical surface such as the exit port of an integrating sphere or the real image in an imaging system, where it is identical to the irradiance on to the surface.

The irradiance quantity itself says absolutely nothing about the directionality of the flux. For example, if the three cases in the figure below all have the same flux per unit area striking the surface, then they all have the same irradiance. Because of this ambiguity, specifications for illumination systems often qualify the irradiance quantity with an added description of the desired directional properties [3].

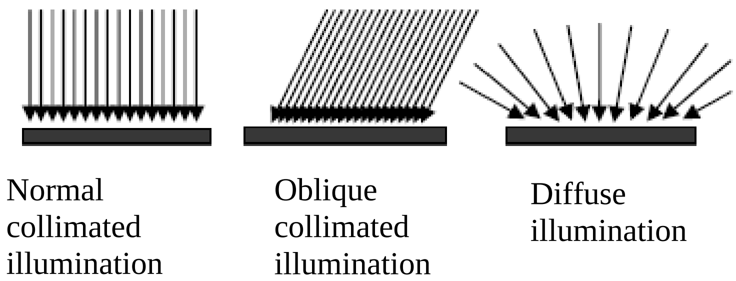
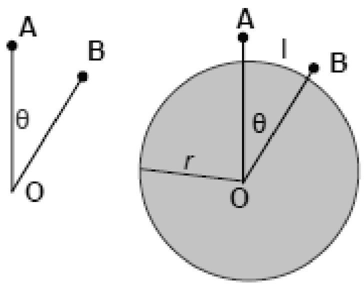


Figure 1.2 Types of Illuminations.

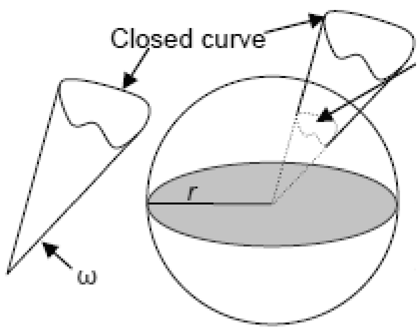
A plane angle θ, made up of the lines from two points meeting at a vertex, is defined by the arc length of a circle subtended by the lines and by the radius of that circle, as shown below. The dimensionless unit of plane angle is the radian, with 2π radians in a full circle.



$\theta = l/r$ (radians)

2π radians in a full circle

Figure.1.3 A plane angle.



area *a*, on surface of sphere

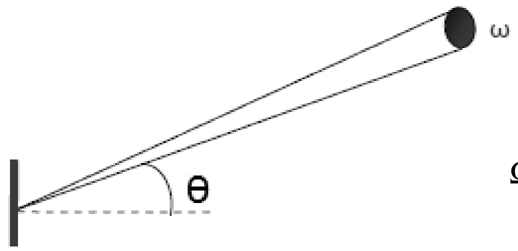
$\omega = a/r^2$ (steradians)

4π steradians in a full sphere

Figure 1.4 Solid angle.

Intensity I, is the flux per unit solid angle. It is the amount of flux from a point source contained in a small angular volume [4]. A source can be considered a point source for this application if the irradiance falls off as the inverse square of the distance from the source. Intensity, for a given source, can vary with direction.

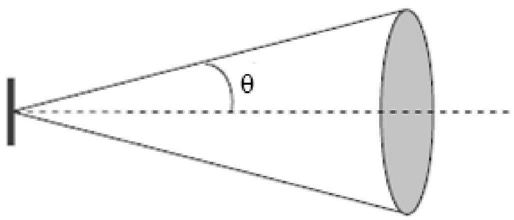
Radiance L, applies to extended sources and surfaces. It is the flux per unit solid angle per unit projected area of the source or surface. The projected area is the projection of the area onto a surface normal to the direction of view and is equal to the actual area times the cosine of the angle between the surface normal and the direction of view. Radiance can vary with position on a surface, and like intensity, it can vary with direction. A source or surface with constant radiance in all directions is called Lambertian. A Lambertian source or surface has intensity that varies with the cosine of the angle with the surface normal [5].



$$\Omega = \omega \cos \theta$$

Figure 1.5 Solid angle- surface normal.

When the solid angle is large enough so that the angle with the surface normal is not the same over the entire solid angle, the total projected solid angle must be computed by integrating the incremental projected solid angles. For some special cases, the integration results in simple expressions, such as for a large circular cone that is normal to a surface and subtends a half angle θ.



$$\Omega = \pi \sin^2 \theta$$

Figure 1.6 Solid angle – large circular cone.

1.2. b Spectral Quantities

In the spectral dimension of illumination, the most general view looks at the spectral density the amount of radiation per unit wavelength interval. In terms of the four spatial quantities already considered, the spectral quantities are spectral flux Φ_λ; spectral irradiance E_λ; spectral intensity I_λ; and spectral radiance L_λ.

These quantities, usually written with a subscript to indicate that they are integrable, must be integrated to determine the amount of radiation in a particular spectral band. For example, the total radiant flux, Φ (in units of watts), in the band between wavelength λ1 and wavelength λ2 is;

$$\Phi\,(\lambda 1, \lambda 2) = \int_{\lambda 2}^{\lambda 1} \phi_\lambda\,(\lambda)\,.\,d\lambda \qquad (1.1)$$

Similar expressions can be written for the total irradiance, E (watts/m^2); total radiant intensity, I (watts/ sr); and total radiance, L (watts / m^2 sr).

Photometry measures the response of the human eye to light. Although not everyone has exactly the same response, the standardized CIE 1924 luminous efficiency function works very well for most people. (The CIE is the International Commission on Illumination.) The unit of luminous (photopic) flux is the lumen [6]. The luminous flux is found from the spectral flux and the V(λ) function from the following relationship:

$$\text{Luminous flux} = 683 \int \Phi_\lambda\,(\lambda)\,.\,V(\lambda)\,.\,d\,\lambda \qquad (1.2)$$

The factor of 683 in this equation comes directly from the definition of the fundamental unit of luminous intensity, the candela.

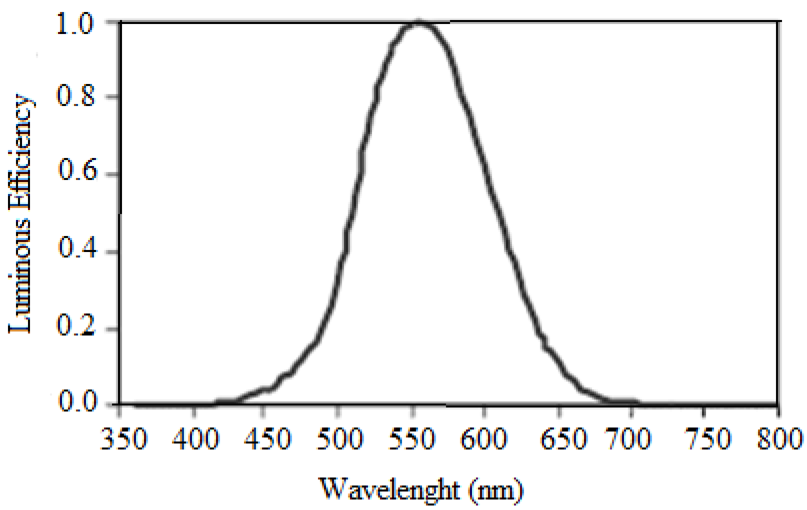


Figure 1.7 The variation of luminous efficiency with the wavelenght.

The notation of lighting maybe given as follows;

• The photopic quantities of flux, irradiance, intensity, and radiance are called luminous flux, illuminance, luminous intensity, and luminance, respectively.

• These quantities are sometimes notated with a subscript “v” , as Φv, Ev, Iv, and Lv. But often the subscript is omitted since the meaning is usually clear from the context, and it could be confused with the subscript notation often reserved for integrable quantities [7].

• The designations Φ, E, I, and L are common but not universally standard. Another set of symbols sometimes used is P, H, J, and N, respectively, for radiometric quantities; P_λ, H_λ, J_λ, and N_λ for spectral quantities; and F, E, I, and B for the corresponding photometric quantities.

• Solid angle and projected solid angle are not always distinguished by ω and Ω, respectively.

Table 1.1 Typical illuminance in different environments [8].

Illumination condition	**Illuminance**	
Full moon	1	lux
Street lighting	10	lux
Home lighting	30 to 300	lux
Office desk lighting	100 to 1000	lux
Surgery lighting	10 000	lux
Direct sunlight	100 000	lux

Table 1.2 Photometric radiometric units [9].

Photometric unit	Dimension	Radiometric unit	Dimension
Luminous flux	lm	Radiant flux (optical power)	W
Luminous intensity	Lm / sr = cd	Radiant intensity	W / sr
Illuminance	Lm / m^2 = lux	Irradiance (power density)	W / m^2
Luminance	Lm / (sr m^2) = cd / m^2	Radiance	W / (sr m^2)

CHAPTER 2

POWER LED

The power LED lighting is more and more important in energy-saving and non-mercury lighting. They will take the place of the traditional lighting such as incandescent bulbs, mercury lamps, gas-discharge lamps, halogens and CFL's. Nowadays, energy saving is becoming more and more critical as a new issue in the world. Power LED's character of energy saving brings it more and more focus and research support [10].

2.1 Principle Of Light-Emitting Diodes (LED)

The high power light-emitting diode is also a diode, so the principle of power LEDs is the same as a normal pn junction. The principle of power LEDs emitting light is spontaneous recombination of electron-hole pairs. An electron-hole recombination process is illustrated in Fig.2.1. For a simpler view, assuming that electrons in the conduction band and holes in the valence band have a parabolic dispersion relationship.

- $E_{electron} = E_c + \frac{h^2 k^2}{2 m_e} \qquad E_{hole} = E_v - \frac{h^2 k^2}{2 m_h}$ (2.1)

Where m_e is the mass of electron, m_h is the mass of hole, and k is the wave vector. Thus, when an electron-hole pair recombine together, an energy of hv is emitted in the form of photon, which is a particle of light. As it is known, electrons on the bottom of conduction band are easier to recombine with holes on the top of valence band [11]. Above the bottom of conduction band, electrons also probably release energy to give photons, thus hv of those emission is larger than those on the bottom of conduction band, which means they emit shorter wavelength light.

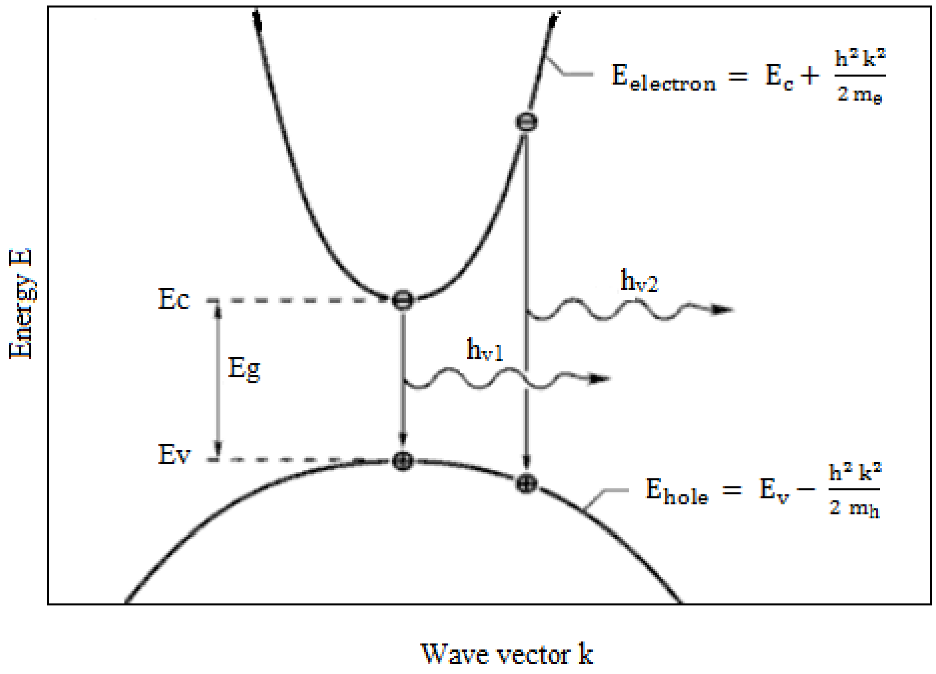


Figure 2.1 Recombination of electron-hole pair and light emission.

Power LED converts input electrical energy into light emission; so, a forward bias is applied on the LED device [12]. Then, as looked at the pn junction, under a forward bias, the minority will diffuse to the other side of neutral region, thus recombining with the majority of the other side, emitting photons of hv, as Fig.2.2. In a schematic representation of cross-section, it is possible to see the light emitting from the interface of pn junction, and that p-type region is small enough to avoid light absorption by p-type material. For further consideration, it is commonly advised to choose a material "transparent" to the emitted light.

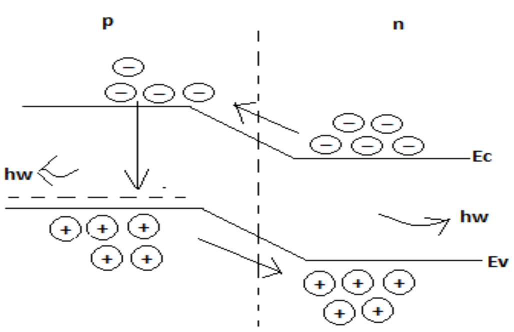


Figure 2.2 Light emitting in the pn junction.

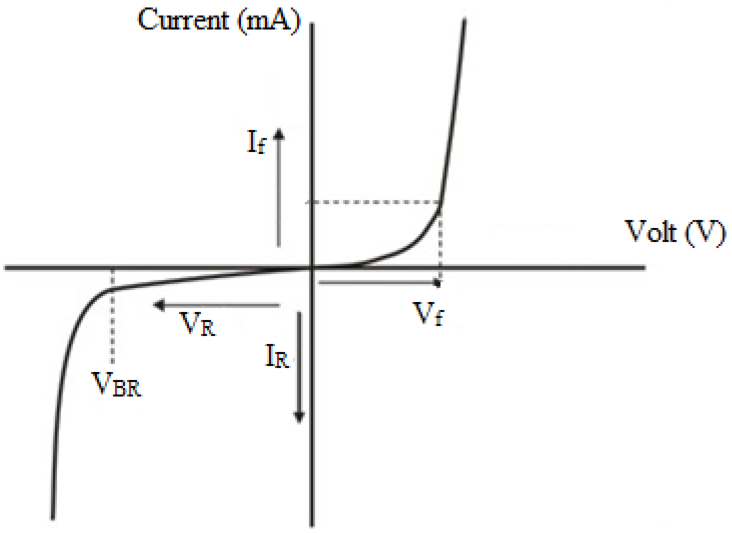


Figure 2.3 LED current - voltage characteristic.

2.2 White light with LED

There are two ways of producing white light using LEDs. First is to use individual LEDs these are red, green, and blue and then, mix all the colors. Second way is to use a phosphor material. This way like a fluorescent light bulb works [12].

2.2. a White Light with RGB Systems

First method is the most common to use red, green, and blue LEDs. The individual color LEDs typically have slightly different emission patterns even if they are made as a single unit [13]. these are seldom used to produce white lighting. Components of white light colors is denoted in Fig.2.4.

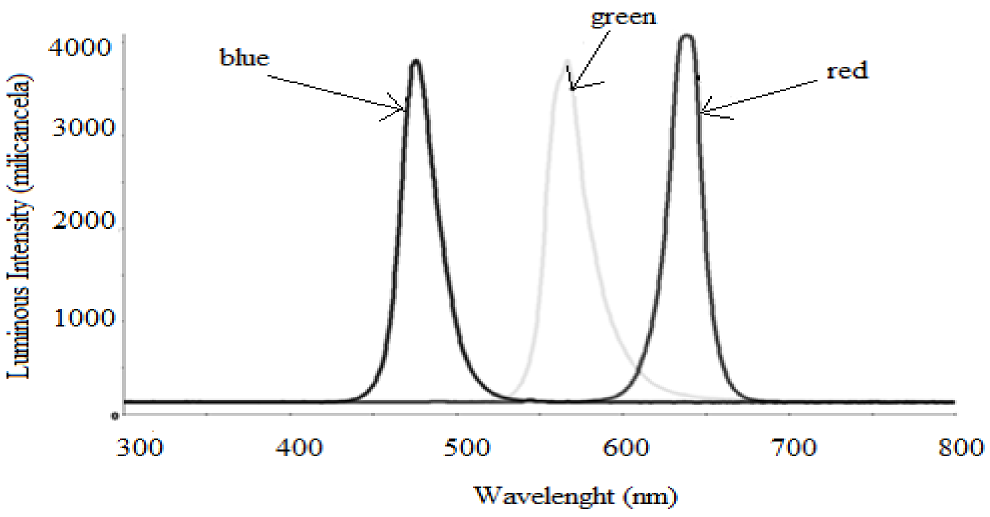


Figure 2.4 Components of white light colours.

2.2.b White Light with Phosphor-based LEDs

This method involves coating LEDs of one color (mostly blue LEDs made of InGaN) with phosphor of different colors to form white light [14]. The resultant LEDs are called phosphor-based white LEDs. A fraction of the blue light undergoes the Stokes shift being transformed from shorter wavelengths to longer. Depending on the color of the original LED, phosphors of different colors can be employed [15].

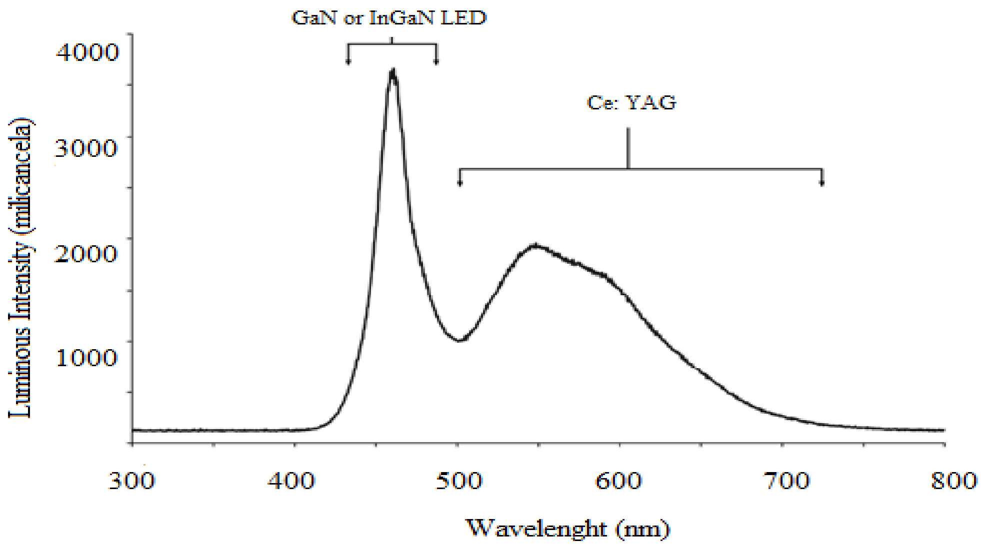


Figure 2.5 LED intensity – wavelenght graph.

2.3 Advantages of Power LED Lighting

LED lighting advantages are given as follows [16];

Luminous Efficiency: LEDs emit more light per watt than other lighting devices.

Colors: LEDs can emit light of an intended color without using any color filters as traditional lighting methods need..

Size: LEDs can be very small and are easily populated onto printed circuit boards.

On/Off time: LEDs light up very quickly. A typical red indicator LED will achieve full brightness in under a microsecond.

Dimming: LEDs can very easily be dimmed either by pulse-width modulation or lowering the forward current.

Cool light: In contrast to most light sources, LEDs radiate very little heat in the form of IR that can cause damage to sensitive objects or fabrics.

Slow failure: LEDs mostly fail by dimming over time, rather than the abrupt failure of incandescent bulbs.

Lifetime: LEDs can have 50.000-100.000 hours relatively long useful life.

Shock resistance: It is difficult to damage with shock, unlike fluorescent and incandescent bulbs, which are fragile.

Focus: The solid package of the LED can be designed to focus its light.

2.4 Disadvantages of Power LED Lighting

High initial price: LEDs are currently more expensive, price per lumen, on an initial capital cost basis, than most conventional lighting technologies.

Temperature dependence: LED performance largely depends on the ambient temperature of the operating environment [17].

Voltage sensitivity: LEDs must be supplied with the voltage above the threshold and a current below the rating.

Electrical polarity: Unlike incandescent light bulbs, which illuminate regardless of the electrical polarity, LEDs will only light with correct electrical polarity.

2.5 Power LEDs Lighting Applications

With the development of high-efficiency and high-power LEDs, it has become possible to use LEDs in lighting and illumination. Replacement light bulbs have been made, as well as dedicated fixtures and LED lamps. LEDs are used as street lights, architectural lighting, automotive lighting, cars, motorcycles, and bicycle lights, backlighting for LCD televisions and lightweight laptop, medical and educational applications and etc.

2.6 Types of Other Artificial Light Sources

2.6. a Incandescent Bulb

Incandescent Bulb is the standard light bulb, but incandescents exists in a very wide range of shapes, forms, voltages, colors and applications. It is produced a great spectrum, with quite poor energy efficiency and a short life span. [18].

2.6. b Halogens

Halogens are incandescent lights where the gas chamber is filled with a halogen gas type. Halogens tend to be somewhat higher in performance than normal incandescents, with slightly higher efficiency, and a longer life span, but typically cost more [18].

2.6. c Compact Fluorescents (CFLs)

These lamps consist of a gas filled tube and a 'ballast' which is currently mostly electronic, that prevents the lamp from getting over-excited and burning up internally. CFL's save energy by emitting light in just a few peak wavelengths, and almost no infrared, reducing the energy needed to operate [19].

2.6. d Gas-discharge Lamps

Gas-discharge lamps work by sending a current through ionized gas. Neon lights from the colorful street signs, which are a type of gas-discharge lamp, but there are a great many other types [20]. Some gas-discharge lamps contain mercury, therefore, they should be handled carefully because mercury is a very poisonous substance.

2.7 Comparison Of Power LED Lighting Technologies with Present Lighting Devices

Table 2.1 Luminous efficiencies of different light sources. [21].

Light Source	**Luminous Efficiency**	
Edison's first light bulb	1.4	lm/W
Tungsten filament light bulb	15 – 20	lm/W
Quartz halogen light bulbs	25 – 25	lm/W
Fluorescent light tubes and compact bulbs	50 – 80	lm/W
Mercury vapor light bulb	50 – 60	lm/W
Metal halide light bulbs	80 – 125	lm/W
Power LED	80 – 160	lm/W

The luminous efficiency of a light source, measured in units of lm/W, is the luminous flux of the light source divided by the electrical input power.

Luminous efficiency = Φ_{lum} / (IV) where the product (IV) is the electrical input power of the device [22].

CHAPTER 3

POWER LED DRIVERS

Power LEDs drive with current and voltage-limiting driver circuits. Driver circuits have linear regulator and switching regulator types. In accordance with the aim of their usage, these are buck-based, boost-based and boost-buck based power LED drivers [23].

3.1 Buck-Based Power LED Drivers

The buck converter is the simplest of the switching drivers, and is a step-down converter for applications where the load voltage does not exceed more than about 85 % of the supply voltage. The limit of about 85 % is due to switching delays in the control system [24]. In a buck converter circuit, a power MOSFET is usually used to switch the supply voltage across an inductor and LED load connected in series. The inductor is used to store energy when the MOSFET is turned on. This energy is then used to provide current for the LED when the MOSFET is turned off [25]. A diode across the LED and inductor circuit provides a return path for the current during the MOSFET off time. A simple schematic buck driver circuit is denoted in Fig.3.1.

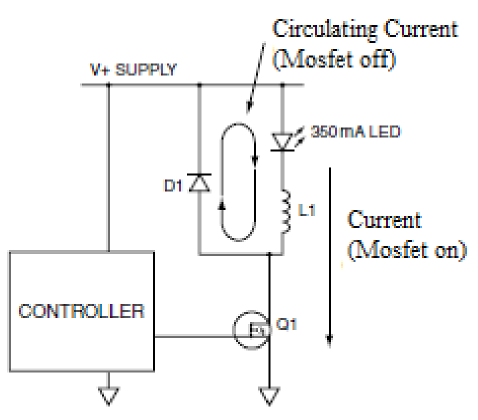


Figure 3.1 Simplified buck driver circuit.

3.2 Boost - Based Power LED Driver

Boost drivers are ideal for LED driver applications where the LED string voltage is greater than the input voltage. Normally, a boost converter would only be used when the output voltage minimum is about 1.5 times the input voltage [26]. Simplified boost – based power LED driver circuit is shown in Fig.3.2.

The advantages of boost - based power LED drivers maybe given as follows;

a) The converter can easily be designed to operate at efficiencies greater than 90 % [27].

b) Both the MOSFET and LED string are connected to a common ground. This simplifies sensing of the LED current, unlike the buck converter where it has chosen either a high side MOSFET driver or a high side current sensor [28].

c) The input current can be continuous, which makes it easy to filter the input ripple current and thus easier to meet any required conducted EMI and EMC standards [29].

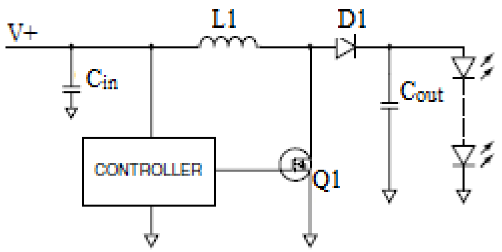


Figure 3.2 Simplified boost based power LED driver circuit.

3.3 Boost-Buck Based Power LED Driver

A boost-buck converter is a single-switch converter, which consists of a cascade of a boost converter followed by a buck converter [27]. The power train of typical boost-buck circuit topology is given in Fig.3.3.

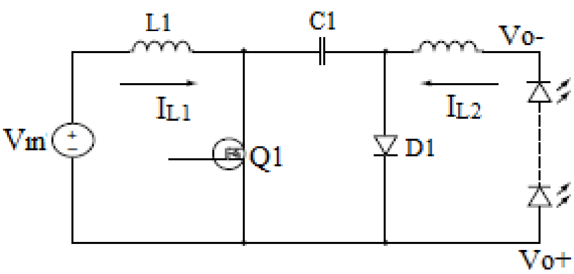


Figure 3.3 Boost-buck based power LED driver circuit.

CHAPTER 4

LED DRIVER CIRCUIT DESIGN USING RESISTORS

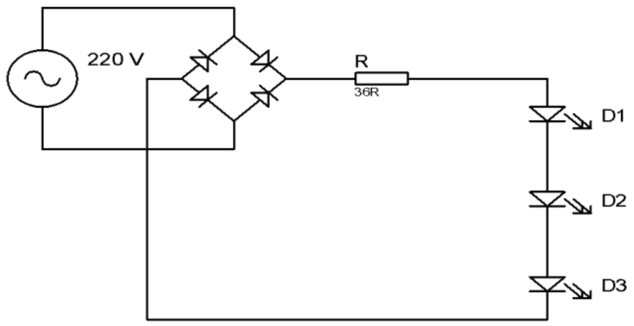


Figure 4.1 Power LED driver circuit design using a resistor

4.1. Definition Driver Circuit

At this designing the buck-based circuit, power LEDs are driven with determined resistor value. According to increasing input voltage values, the resistor value that needs to be connected to power LEDs in series were calculated. The power values that were spent on circuit and circuit efficiencies were computed.

LED luminous values were measured by applying different LED Current. So it seems, 320mA was eligible for our study. When 320mA was applied to total 3 LEDs, it emits approximately 260 lm illumination. These parameter calculations are tabulated as follows in Table.4.1.

Table 4.1 LED Current and calculated illuminations values.

V_{in}	R	I_{LED}	$Ø_{LED}$
V	Ω	mA	lm
24	2808	5	6
24	1404	10	11
24	280	50	56
24	200	70	78
24	156	90	101
24	117	120	135
24	100	140	157
24	87	160	178
24	70	200	205
24	63	220	230
24	56	250	243
24	50	280	257
24	46	300	260
24	43	320	260
24	42	330	260
24	40	350	260
24	39	360	260

Where is the circuit input voltage V_{in}, series resistor value is R, LED current is I_{LED} and LED luminous flux is $Ø_{LED}$.

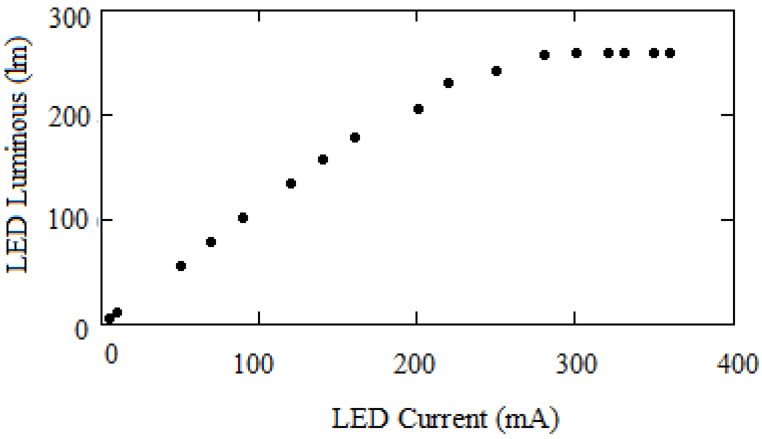


Figure 4.2 LED current and luminous graph. LED luminous reaches 320mA of maximum driving current.

Calculation of parameters for 320 milliamps of current be constant:

I_o = 0.32 A, V_f = The power LED threshold voltage value, V_p = Input Voltage,

- $P_{out} = I_o \times V_f$ (4.1)
- $R = (V_p - V_f) / I_o$ (4.2)
- $P_R = I_o \times V_R$ (4.3)
- $P_{total} = P_{out} + P_R$ (4.4)
- $Efficiency = P_{out} / P_{total}$ (4.5)

Table 4.2 Parameter calculations based on varying input voltages.

V_{in}	R	I_{LED}	V_R	V_{LED}	P_R	P_{out}	$Ø_{LED}$	P_{total}	Efficiency
V	Ω	mA	V	V	W	W	Lm	W	%
24	44	320	14,04	9,96	4,49	3,19	255	7,68	41,51
26	50	320	16,00	10,00	5,12	3,20	256	8,32	38,46
28	56	320	17,92	10,08	5,73	3,23	258	8,96	36,00
30	63	320	20,04	9,96	6,41	3,19	255	9,60	33,21
32	69	320	22,02	9,98	7,05	3,19	256	10,24	31,20
34	75	320	24,00	10,00	7,68	3,20	256	10,88	29,41
36	81	320	26,02	9,98	8,33	3,19	256	11,52	27,73
38	88	320	28,03	9,97	8,97	3,19	255	12,16	26,23
40	94	320	30,02	9,98	9,61	3,19	256	12,80	24,96
42	100	320	32,00	10,00	10,24	3,20	256	13,44	23,81
44	106	320	33,92	10,08	10,85	3,23	258	14,08	22,91
46	112	320	35,84	10,16	11,47	3,25	260	14,72	22,09
48	118	320	37,76	10,24	12,08	3,28	262	15,36	21,33
50	125	320	40,00	10,00	12,80	3,20	256	16,00	20,00
52	131	320	41,92	10,08	13,41	3,23	258	16,64	19,38
54	137	320	43,84	10,16	14,03	3,25	260	17,28	18,81
56	143	320	45,76	10,24	14,64	3,28	262	17,92	18,29
58	150	320	48,00	10,00	15,36	3,20	256	18,56	17,24
60	156	320	49,92	10,08	15,97	3,23	258	19,20	16,80

Where is the circuit input voltage V_{in}, series resistor value is R, LED current is I_{LED} resistor voltage value is V_R, LED voltage value is V_{LED}, consumed power in resistor is $P_{R,}$ circuit output power is P_{out}, LED luminous flux is $Ø_{LED}$ and total power is P_{total}, efficiency is circuit output efficiency.

4.2 Calculations of Driver Circuit Parameters

In order to calculate driver circuit parameters, the following activities were carried out;

- Circuit input voltages range between 24 to 60 volts,
- Circuit current was stabilized at 320 milliamps due to the calculated resistor serial values connected to the LED,
- The resistor value was chosen closest to universal,
- Power LED output voltages were measured,
- Power LED output power was calculated,
- Power LED luminous values were measured,
- Circuit output efficiency was calculated.

4.2.a Input Voltage – LED Current

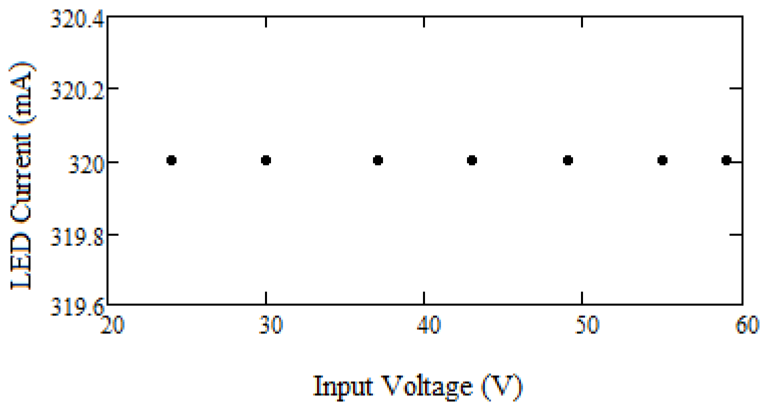


Figure 4.3 The current value remains constant with the calculated resistor value as increased input voltage values.

4.2.b Input Voltage – Circuit Total Power

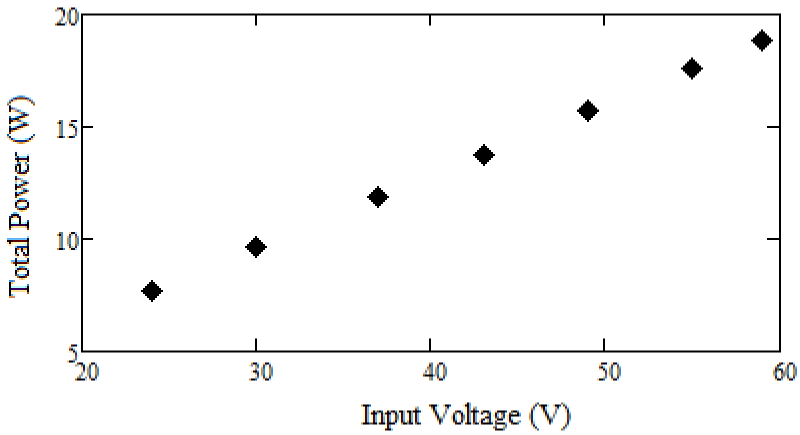


Figure 4.4 The variation of circuit total power with the input voltage.

4.2.c Input Voltage – Circuit Output Efficiency

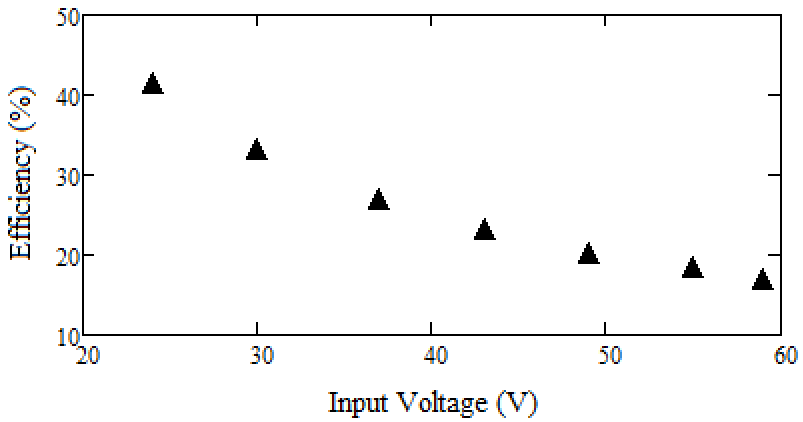


Figure 4.5 The variation of circuit efficiency with the input voltage.

As increasing input voltage from 24V to 60V yield rate decreases from 40 % to 16%.

4.3 LED Temperature – Circuit Output Efficiency

Table 4.3 The variation of LED current-voltage values with the LED temperature under the constant input voltage.

V_{in}	R	T	I_{LED}	V_{LED1}	P_{out}	P_R	P_{total}	Efficiency
V	**Ω**	**^{0}C**	**mA**	**V**	**W**	**W**	**W**	**%**
24	44	25	320	3.90	3.74	14.08	17.82	0.210
24	44	30	321	3.88	3.74	14.12	17.86	0.209
24	44	35	322	3.87	3.74	14.17	17.90	0.209
24	44	40	324	3.85	3.74	14.26	18.00	0.208
24	44	45	325	3.83	3.74	14.30	18.04	0.207
24	44	50	327	3.82	3.74	14.39	18.13	0.206
24	44	55	328	3.81	3.75	14.43	18.18	0.206
24	44	60	329	3.79	3.74	14.48	18.22	0.205
24	44	65	331	3.78	3.76	14.56	18.32	0.205
24	44	70	332	3.73	3.72	14.61	18.33	0.203
24	44	75	334	3.70	3.71	14.70	18.40	0.201

4.3.1 LED Current – Temperature

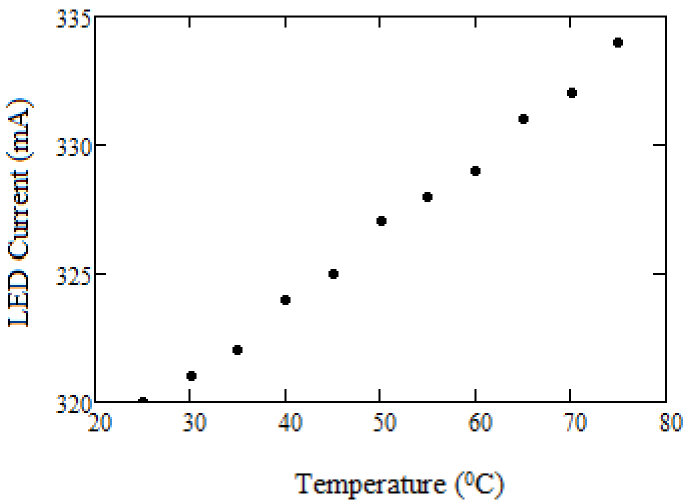


Figure 4.6 Current value on the LED increased due to the increasing LED temperature

4.3.2 LED Temperature – Output Efficiency

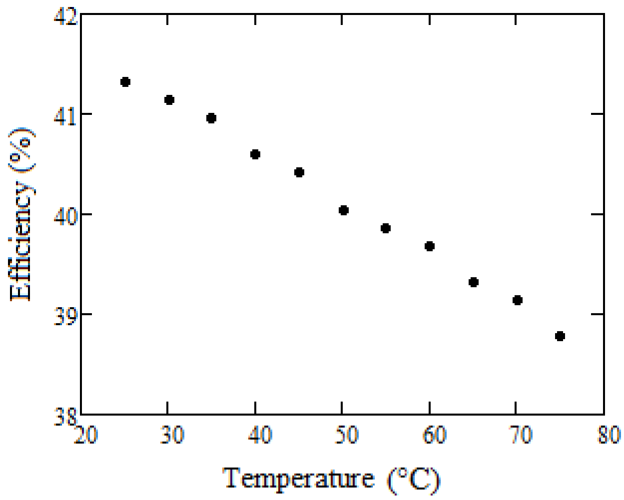


Figure 4.7 The graph of the circuit efficiency against the LED temperature.

As the increasing the LED temperature, the circuit efficiency decreases from 41.3 % to 38.7 %.

4.4 Advantage Of Driver Circuit with Series Resistors

The circuit has an important advantage over others in that it has a simple structure while having lower costs.

4.5 Disadvantage Of Driver Circuit With Series Resistors

High amount of power spent on the resistor decreases overall yield of the circuit. Because of low yield values, of the driver circuit design of it is not preferred [29]. In addition esides, there is much heating on LEDs because the power spent on the resistor is converted into heat on the circuit. The span life of LEDs decreases.

CHAPTER 5

DESIGNING DRIVER CIRCUIT WITH LINEAR REGULATORS

A lineer regulator converts rectified voltage into current on the circuit. The value of the current on LEDs is calculated with the determined resistor value. The difference between input voltage and output voltage in the lineer regulator. Hence, a considerable amount of power is wasted in the linear regulator [30]. It is prefered using the LM317 device as it is widely available and affordable.

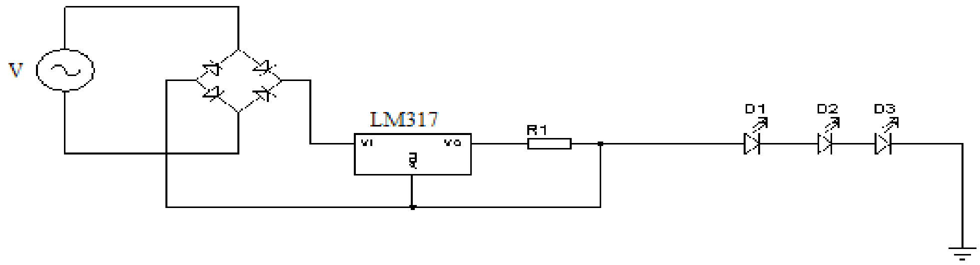
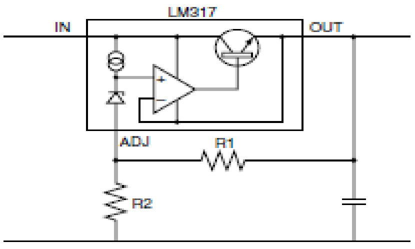


Figure 5.1 Driver circuit design using linear regulator

5.1 Definition of Linear Regulator

The LM317 consists of (1) a power switch, which is an npn transistor; (2) a voltage reference set to produce 1.25V and (3) an operational amplifier (op-amp) to control the power switch, as shown in Fig.5.2..



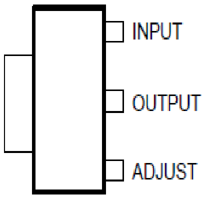


Figure 5.2 The LM317 regulator.

A capacitor on the output terminal also helps with stability. The output voltage is given by the equation as follows;

- $V_{out} = 1.25 \text{ x } \frac{1+ R_2}{R_1}$ (5.1)

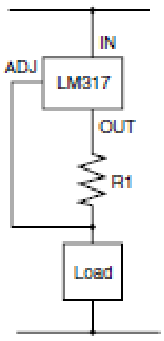


Figure 5.3 Circuits using a voltage regulator as a current limiter.

- $I_{limit} = \frac{1.2}{R_1}$ (5.2)

Table 5.1 The variation of circuit output values with the on input voltage **.**

V_{in}	R	I_{LED}	V_E	V_{LED}	P_E	P_{out}	$Ø_{LED}$	P_{total}	Efficiency
V	**Ω**	**mA**	**V**	**V**	**W**	**W**	**Lm**	**W**	**%**
24	3,9	321	12,30	11,70	3,95	3,76	300,46	7,70	48,75
25	3,9	321	13,30	11,70	4,27	3,76	300,46	8,03	46,80
26	3,9	321	14,30	11,70	4,59	3,76	300,46	8,35	45,00
27	3,9	321	15,30	11,70	4,91	3,76	300,46	8,67	43,33
28	3,9	321	16,30	11,70	5,23	3,76	300,46	8,99	41,79
29	3,9	321	17,30	11,70	5,55	3,76	300,46	9,31	40,34
30	3,9	321	18,30	11,70	5,87	3,76	300,46	9,63	39,00
31	3,9	321	19,30	11,70	6,20	3,76	300,46	9,95	37,74
32	3,9	321	20,30	11,70	6,52	3,76	300,46	10,27	36,56
33	3,91	321	21,30	11,70	6,84	3,76	300,46	10,59	35,45
34	3,91	321	22,30	11,70	7,16	3,76	300,46	10,91	34,41
35	3,91	321	23,30	11,70	7,48	3,76	300,46	11,24	33,43
36	3,91	321	24,30	11,70	7,80	3,76	300,46	11,56	32,50
37	3,91	321	25,30	11,70	8,12	3,76	300,46	11,88	31,62
38	3,91	321	26,30	11,70	8,44	3,76	300,46	12,20	30,79
39	3,91	321	27,30	11,70	8,76	3,76	300,46	12,52	30,00
40	3,91	321	28,30	11,70	9,08	3,76	300,46	12,84	29,25
41	3,91	321	29,30	11,70	9,41	3,76	300,46	13,16	28,54
42	3,91	321	30,30	11,70	9,73	3,76	300,46	13,48	27,86
43	3,91	321	31,30	11,70	10,05	3,76	300,46	13,80	27,21
44	3,91	321	32,30	11,70	10,37	3,76	300,46	14,12	26,59
45	3,91	321	33,30	11,70	10,69	3,76	300,46	14,45	26,00

Where is the circuit input voltage V_{in}, series resistor value is R, LED current is I_{LED} converter voltage drop value is V_E, LED voltage value is V_{LED}, consumed power in circuit is $P_{E,}$ circuit output power is P_{out}, LED luminous flux is $Ø_{LED}$ and total power is Ptotal, efficiency is circuit output efficiency.

5.2 Calculations of Driver Circuit Parameters

In order to calculate driver circuit parameters, the following activities were carried out;

- Input voltage was increased starting from 24V up to 51V.
- The resistor value to be connected in series needed for stabilizing at 320mA of LED current value was calculated, by the equation as follows;

$$I_{limit} = \frac{1.2}{R1} \qquad (5.3)$$

- The resistor value was chosen taking into consideration of universal availability.
- LED output voltages were measured.
- LED output power was calculated with relationship;
- $P_{çıkış} = U_{çıkış} \times I_{limit}$ (5.4)
- LED luminous values were measured.
- Yield calculations were made with the relationship;

$$Efficiency = \frac{Pout}{Ptotal} \qquad (5.5)$$

5.2.a Input Voltage – LED Currents

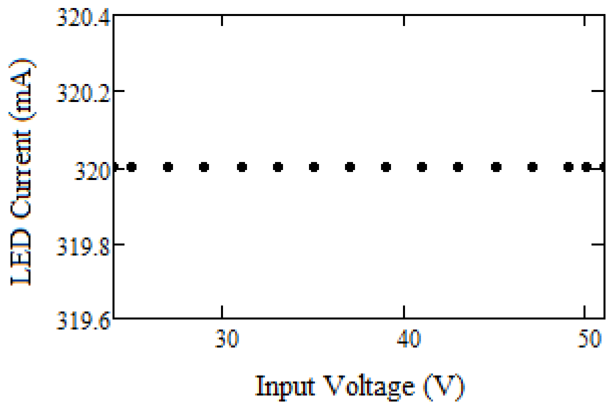


Figure 5.4 The graph of LED current against input voltage. It is seen that LED current remains at the value of 320mA.

5.2.b Input Voltage – Circuit Total Powers

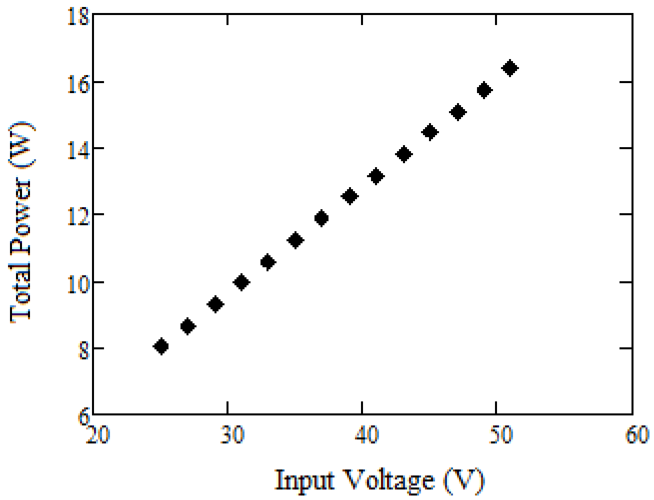


Figure 5.5 The variation of the total power with the input voltage.

5.2.c Input Voltage – Circuit Output Efficieny

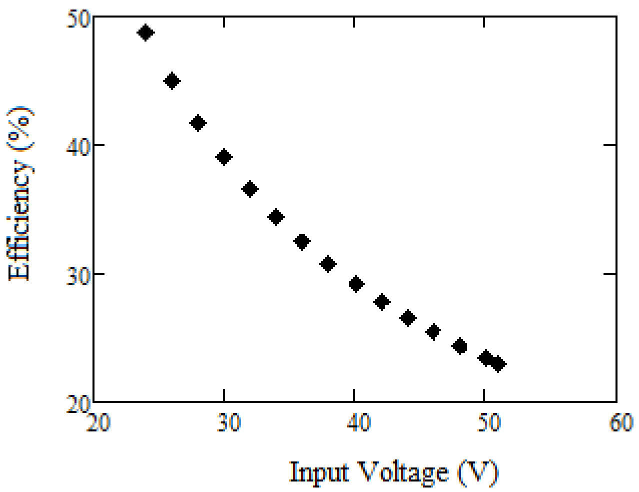


Figure 5.6 The graph of the circuit output efficiency against input voltage.

It is seen that at the interval of 24V - 50V the circuit output efficiency decreases from 48 % to 16 %.

5.3 LED Temperature – Circuit Efficiencies

Table 5.2 The variations of circuit parameters with the LED temperature.

V_{in}	R	T	I_{LED}	V_{LED1}	P_{out}	P_R	P_{total}	Efficiency	V_{in}
V	Ω	^{0}C	mA	V	W	W	W	%	V
24	3,9	25	321	11,7	3,76	1,25	3,95	8,96	0,419
24	3,9	30	321	11,6	3,72	1,25	3,98	8,96	0,416
24	3,9	35	321	11,5	3,69	1,25	4,01	8,96	0,412
24	3,9	40	321	11,5	3,69	1,25	4,01	8,96	0,412
24	3,9	45	321	11,4	3,66	1,25	4,04	8,96	0,409
24	3,9	50	321	11,4	3,66	1,25	4,04	8,96	0,409
24	3,9	55	321	11,3	3,63	1,25	4,08	8,96	0,405
24	3,9	60	321	11,2	3,60	1,25	4,11	8,96	0,401
24	3,9	65	321	11,2	3,60	1,25	4,11	8,96	0,401
24	3,9	70	321	11,1	3,56	1,25	4,14	8,96	0,398
24	3,9	75	321	11,1	3,56	1,25	4,14	8,96	0,398

5.3. a LED Temperature –Circuit Efficiencies

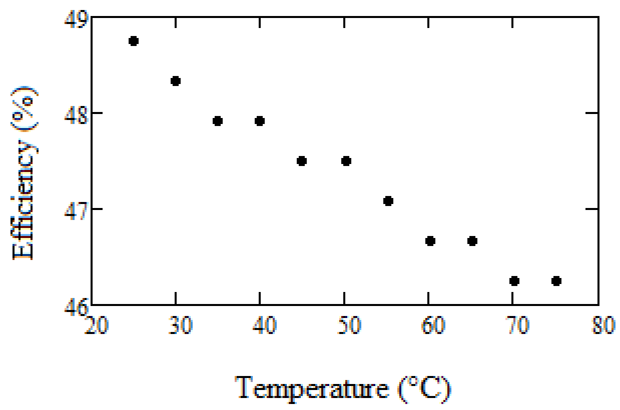


Figure 5.7 The graph of the circuit output efficiency against the LED temperature.

CHAPTER 6

DESIGNING DRIVER CIRCUIT WITH SWITCHING REGULATOR

The use of switching regulators is becoming more pronounced over that of linear regulators because the size reductions in new equipment designs require greater conversion efficiency. The switching regulator has increased application flexibility of output voltage. This is another major advantage of it the output can be less than, greater than, or of opposite polarity to that of the input voltage. MC34063 was prefered due to its availability, affordable cost and high efficiency [31].

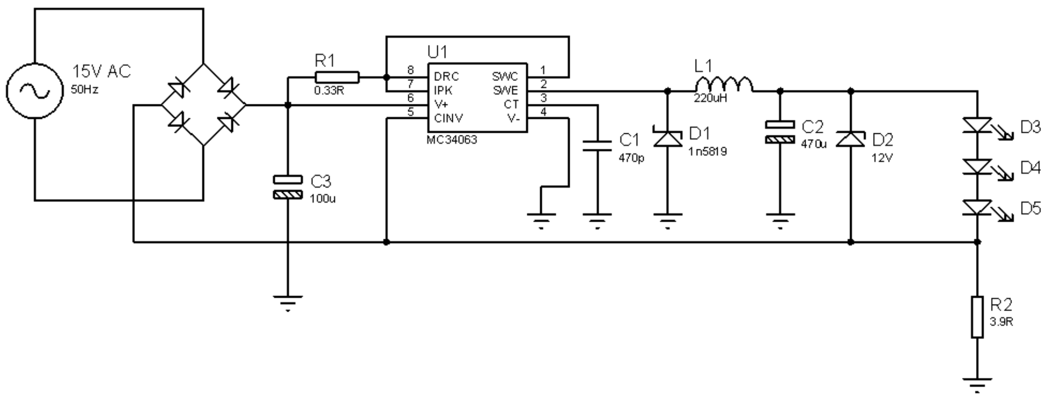


Figure 6.1 Circuit model designed using switching regulator is the study of this thesis.

6.1 Definition of Switching Regulator

The MC34063 series is a monolithic control circuit containing all the active functions required for dc to dc converters [31]. This device contains an internal temperature compensated reference, comparator, controlled duty cycle oscillator with an active peak current limit circuit, driver, and a high current output switch. This series was specifically designed to be incorporated in step−up, step−down and voltage−inverting converter applications. These functions are contained in an 8−pin dual in−line package shown in Fig.6.2.

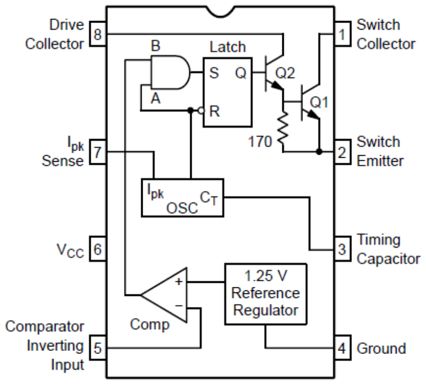


Figure 6.2 The MC34063 switching regulator.

6.2 Step−Down Switching Regulator Operation

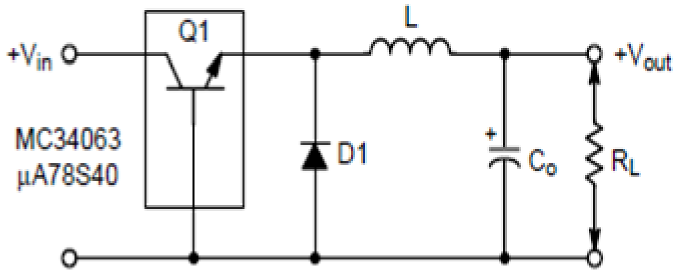


Figure 6.3 The basic step−down switching regulator [3].

Swtiching regulator formulas are given as follows;

- $V_{out} = V_{in} \left(\frac{t_{on}}{t_{on} + t_{off}}\right)$ (6.1)
- $I_L = \left(\frac{V_{in} + V_{sat} - V_{out}}{L}\right) t$ (6.2)
- $I_L = I_{L(pk)} - \left(\frac{V_{out} + V_F}{L}\right) t$ (6.3)
- $I_L = \left(\frac{V_{in} + V_{sat} - V_{out}}{L}\right) t_{on} = \left(\frac{V_{out} + V_F}{L}\right) t_{off} \quad \frac{t_{on}}{t_{off}} = \left(\frac{V_{out} + V_F}{V_{in} + V_{sat} - V_{out}}\right)$ (6.4)
- $\left(\frac{I_{L(pk)}}{2}\right) t_{on} + \left(\frac{I_{L(pk)}}{2}\right) t_{off} = (I_{out} t_{on}) + (I_{out} t_{off})$ (6.5)
- $I_{L(pk)} = 2\, I_{out}$ (6.6)

- $C_T = 4.0 \times 10^{-5} t_{on}$ (6.7)

- $f_{min} = \frac{1}{t_{on\,(max)} + t_{off}}$ (6.8)

- $L_{min} = \left(\frac{V_{in} - V_{sat} - V_{out}}{I_{pk\,(switch)}}\right) t_{on}$ (6.9)

- $V_{ripple(p-p)} = \frac{I_{pk}(t_{on} + t_{off})}{8C_o}$ (6.10)

6.3 Calculations of Driver Circuit Parameters

Table 6.1 Tabulated values of the switching circuit parameters.

V_{in}	$F_{switching}$	C_t	t_{on} / t_{off}	t_{on}	I_{pk}	R_{sc}	L	t_{off}	$t_{on} + t_{off}$
V	kHz	pF	µs	µs	A	mΩ	µH	µs	µs
24	20	1057	1.12	26.42	0.48	625	907	23.59	50.00
24	25	845	1.12	21.13	0.48	625	725	18.87	40.00
24	30	704	1.12	17.61	0.48	625	604	15.72	33.33
24	35	604	1.12	15.09	0.48	625	518	13.48	28.57
24	40	528	1.12	13.21	0.48	625	453	11.79	25.00
24	45	470	1.12	11.74	0.48	625	403	10.48	22.22
24	50	423	1.12	10.56	0.48	625	363	9.43	19.99
24	55	384	1.12	9.61	0.48	625	330	8.57	18.18
24	60	352	1.12	8.81	0.48	625	302	7.86	16.67
24	65	325	1.12	8.13	0.48	625	279	7.26	15.39
24	70	302	1.12	7.55	0.48	625	259	6.74	14.29
24	75	282	1.12	7.04	0.48	625	242	6.29	13.33
24	80	264	1.12	6.60	0.48	625	227	5.90	12.50
24	85	249	1.12	6.22	0.48	625	213	5.55	11.76
24	90	235	1.12	5.87	0.48	625	201	5.24	11.11
24	95	222	1.12	5.56	0.48	625	191	4.97	10.53

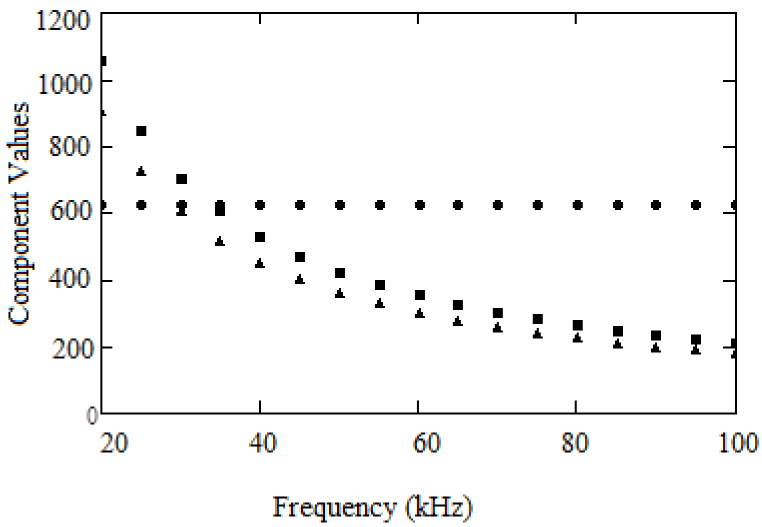


Figure 6.4 The variations of component values with the frequency.

The circuit power loss relationships are given in the following;

- Conduction Loss in Power Switch;

$$P_{swicth,\ cond} = I_L \text{ x } V_{SAT} \text{ x Duty cycle} \quad (6.11)$$

- Conduction Loss in Sensing Resistor;

$$P_{sensing,\ res} = (I_{Lavg} \text{ x } \frac{t_{on}}{t_{off}})^2 \text{ x } R_{sc} \text{ x } 0{,}001 \quad (6.12)$$

- Conduction Loss in Diode;

$$P_{diode,\ cond} = (V_F \text{ x } I_{out}) \text{ x } (1\text{- duty cycle}) \quad (6.13)$$

- Inductor Winding Losses;

$$P_{ind,\ winding} = (I_{out})^2 \text{ x } R_L \quad (6.14)$$

- Static Power Loss;

$$P_{static} = 0{,}003 \text{ x } V_{in} \quad (6.15)$$

- Switching Losses of Power Switch;

$$P_{swicth,\ sw} = V_{in}\ x\ I_{Lavg}\ x\ (\frac{1}{f}) \qquad (6.16)$$

- Core Loss in Inductor. Available in inductor data sheet;

$$P_{core} = \text{from datasheet } 0{,}10\ W \qquad (6.17)$$

- Total Loss;

$$P_{loss,\ total} = (P_{swicth,\ cond} + P_{sensing} + P_{diode,\ cond} + P_{ind,\ winding} + P_{static,\ Ic} + P_{swicth}) \qquad (6.18)$$

- Output Power;

$$P_{out} = V_{out}\ x\ I_{out} \qquad (6.19)$$

- Input Power = Output Power + Total Loss;

$$P_{in} = P_{out} + P_{loss} \qquad (6.20)$$

- Saturation Voltage of Power Switch Transistor. Available in inductor data sheet.

$$V_{sat} = 0{,}1\ V \qquad (6.21)$$

6.3.a Calculations of Circuit Power Losses

Table 6.2 Circuit calculations based on formulas .

Input Voltage	The LED Current	Frequency	Output Voltage	THE POWER CONSUMED ON THE CIRCUIT								Output Power	Total Power	EFFICIENCY
				Pswitch, cond	Psensing, res	Pdiode, cond	Pind, winding	Pstatic, IC	Pswitch, sw	Pcore	Ploss, total			
V	mA	kHz	V	W	W	W	W	W	W	W	W	W	W	%
24	320	20	11.7	0.223	0.080	0.091	0.019	0.072	0.008	0.1	0.593	3.744	4.337	86.33
24	320	25	11.7	0.223	0.080	0.091	0.019	0.072	0.010	0.1	0.595	3.744	4.339	86.29
24	320	30	11.7	0.223	0.080	0.091	0.019	0.072	0.012	0.1	0.597	3.744	4.341	86.25
24	320	35	11.7	0.223	0.080	0.091	0.019	0.072	0.013	0.1	0.599	3.744	4.343	86.21
24	320	40	11.7	0.223	0.080	0.091	0.019	0.072	0.015	0.1	0.600	3.744	4.344	86.18
24	320	45	11.7	0.223	0.080	0.091	0.019	0.072	0.017	0.1	0.602	3.744	4.346	86.14
24	320	50	11.7	0.223	0.080	0.091	0.019	0.072	0.019	0.1	0.604	3.744	4.348	86.10
24	320	55	11.7	0.223	0.080	0.091	0.019	0.072	0.021	0.1	0.606	3.744	4.350	86.06
24	320	60	11.7	0.223	0.080	0.091	0.019	0.072	0.023	0.1	0.608	3.744	4.352	86.03
24	320	65	11.7	0.223	0.080	0.091	0.019	0.072	0.025	0.1	0.610	3.744	4.354	85.98
24	320	70	11.7	0.223	0.080	0.091	0.019	0.072	0.027	0.1	0.612	3.744	4.356	85.95
24	320	75	11.7	0.223	0.080	0.091	0.019	0.072	0.029	0.1	0.614	3.744	4.358	85.91
24	320	80	11.7	0.223	0.080	0.091	0.019	0.072	0.031	0.1	0.616	3.744	4.360	85.87
24	320	85	11.7	0.223	0.080	0.091	0.019	0.072	0.033	0.1	0.618	3.744	4.362	85.83
24	320	90	11.7	0.223	0.080	0.091	0.019	0.072	0.035	0.1	0.620	3.744	4.364	85.79
24	320	95	11.7	0.223	0.080	0.091	0.019	0.072	0.036	0.1	0.622	3.744	4.366	85.76
24	320	100	11.7	0.223	0.080	0.091	0.019	0.072	0.038	0.1	0.624	3.744	4.368	85.72

6.3.b Frequency – Circuit Power Losses

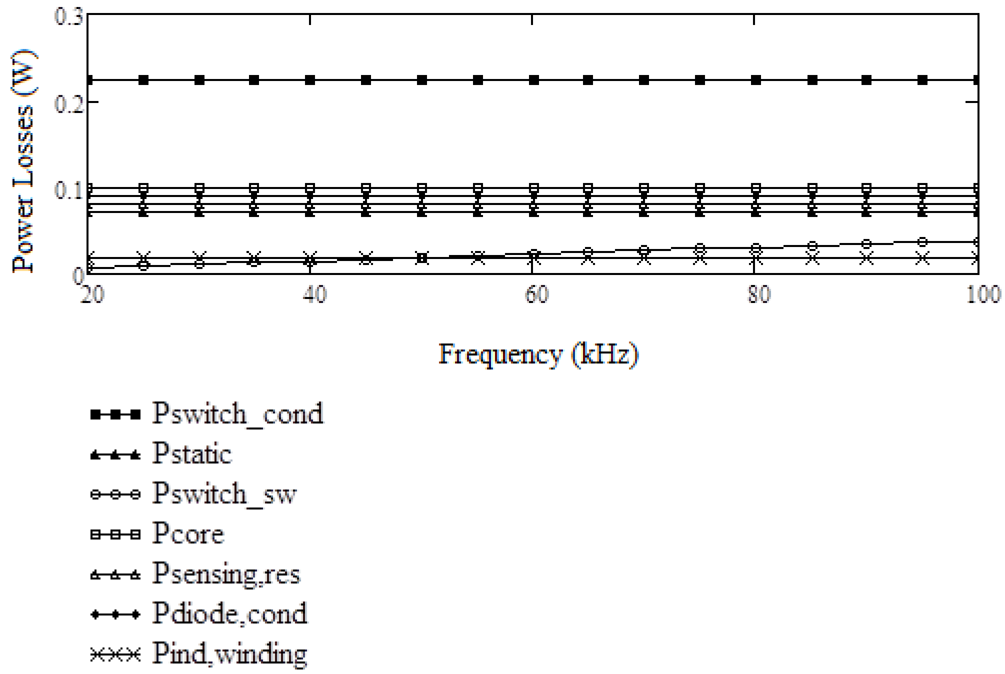


Figure 6.5 Graph of power losses against frequency.

6.3.c Frequency – Circuit Efficiencies

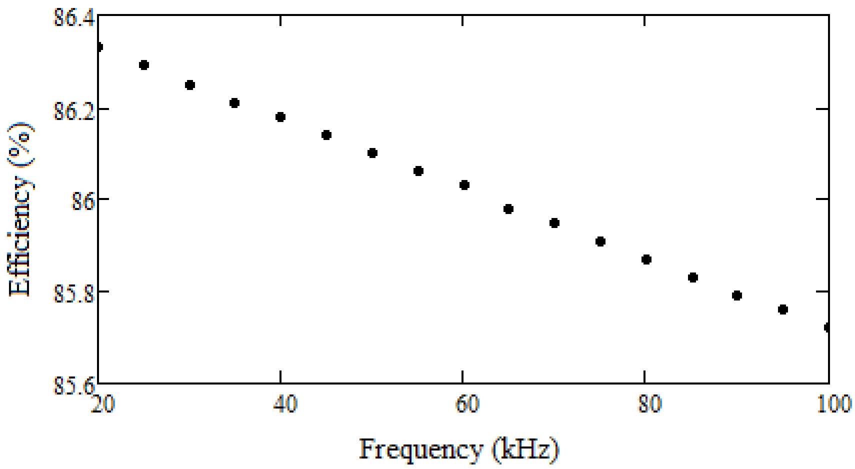


Figure 6.6 Graph of output efficiency against frequency.

6.4 Calculations of Driver Circuit Parameters

Table 6.3 Tabulated values of circuit parameters against input voltage.

V_{in}	C_t	t_{on}/t_{off}	t_{on}	I_{pk}	R_{sc}	L	t_{off}	$t_{on}+t_{off}$
V	**pF**	**µs**	**µs**	**A**	**mΩ**	**µH**	**µs**	**µs**
24	1057	1.12	26.4	0.48	625	907	23.58	50.00
25	1013	1.03	25.3	0.48	625	948	24.67	50.00
26	973	0.95	24.3	0.48	625	987	25.67	50.00
27	936	0.88	23.4	0.48	625	1022	26.60	50.00
28	902	0.82	22.5	0.48	625	1055	27.46	50.00
29	870	0.77	21.7	0.48	625	1086	28.26	50.00
30	840	0.72	21.0	0.48	625	1114	29.00	50.00
31	812	0.68	20.3	0.48	625	1141	29.69	50.00
32	786	0.65	19.7	0.48	625	1166	30.34	50.00
33	762	0.62	19.1	0.48	625	1189	30.95	50.00
34	739	0.59	18.5	0.48	625	1211	31.52	50.00
35	718	0.56	17.9	0.48	625	1232	32.06	50.00
36	697	0.54	17.4	0.48	625	1251	32.57	50.00
37	678	0.51	17.0	0.48	625	1270	33.05	50.00
38	660	0.49	16.5	0.48	625	1287	33.50	50.00
39	643	0.47	16.1	0.48	625	1304	33.94	50.00
40	626	0.46	15.7	0.48	625	1320	34.34	50.00

Table 6.4 Circuit Losses Calculations (f=20kHz)

Input Voltage	LED Current	Frequency	Output Voltage	THE POWER CONSUMED ON THE CIRCUIT								Output Power	Total Power	LED Luminous	EFFICIENCY
				Pswitch, cond	Psensing, res	Pdiode, cond	Pind, winding	Pstatic, IC	Pswitch, sw	Pcore	Ploss, total				
V	mA	kHz	V	W	W	W	W	W	W	W	W	W	W	lm	%
24	320	**20**	11.7	0.223	0.080	0.091	0.019	0.072	0.008	0.1	0.593	3.744	4.337	299.52	**86.33**
25	320	**20**	11.7	0.214	0.067	0.095	0.019	0.075	0.008	0.1	0.578	3.744	4.322	299.52	**86.62**
26	320	**20**	11.7	0.205	0.057	0.099	0.019	0.078	0.008	0.1	0.567	3.744	4.311	299.52	**86.84**
27	320	**20**	11.7	0.197	0.050	0.102	0.019	0.081	0.009	0.1	0.558	3.744	4.302	299.52	**87.02**
28	320	**20**	11.7	0.190	0.043	0.105	0.019	0.084	0.009	0.1	0.551	3.744	4.295	299.52	**87.17**
29	320	**20**	11.7	0.183	0.038	0.108	0.019	0.087	0.009	0.1	0.546	3.744	4.290	299.52	**87.28**
30	320	**20**	11.7	0.177	0.034	0.111	0.019	0.090	0.010	0.1	0.541	3.744	4.285	299.52	**87.37**
31	320	**20**	11.7	0.171	0.030	0.114	0.019	0.093	0.010	0.1	0.538	3.744	4.282	299.52	**87.44**
32	320	**20**	11.7	0.166	0.027	0.117	0.019	0.096	0.010	0.1	0.535	3.744	4.279	299.52	**87.50**
33	320	**20**	11.7	0.161	0.024	0.119	0.019	0.099	0.011	0.1	0.533	3.744	4.277	299.52	**87.54**
34	320	**20**	11.7	0.156	0.022	0.121	0.019	0.102	0.011	0.1	0.531	3.744	4.275	299.52	**87.57**
35	320	**20**	11.7	0.151	0.020	0.123	0.019	0.105	0.011	0.1	0.530	3.744	4.274	299.52	**87.59**
36	320	**20**	11.7	0.147	0.018	0.125	0.019	0.108	0.012	0.1	0.529	3.744	4.273	299.52	**87.61**
37	320	**20**	11.7	0.143	0.017	0.127	0.019	0.111	0.012	0.1	0.529	3.744	4.273	299.52	**87.62**
38	320	**20**	11.7	0.139	0.016	0.129	0.019	0.114	0.012	0.1	0.529	3.744	4.273	299.52	**87.62**
39	320	**20**	11.7	0.139	0.014	0.130	0.019	0.117	0.012	0.1	0.529	3.744	4.273	299.52	**87.62**
40	320	**20**	11.7	0.132	0.013	0.132	0.019	0.120	0.013	0.1	0.529	3.744	4.273	299.52	**87.61**

6.4.a Input Voltage – Power Losses

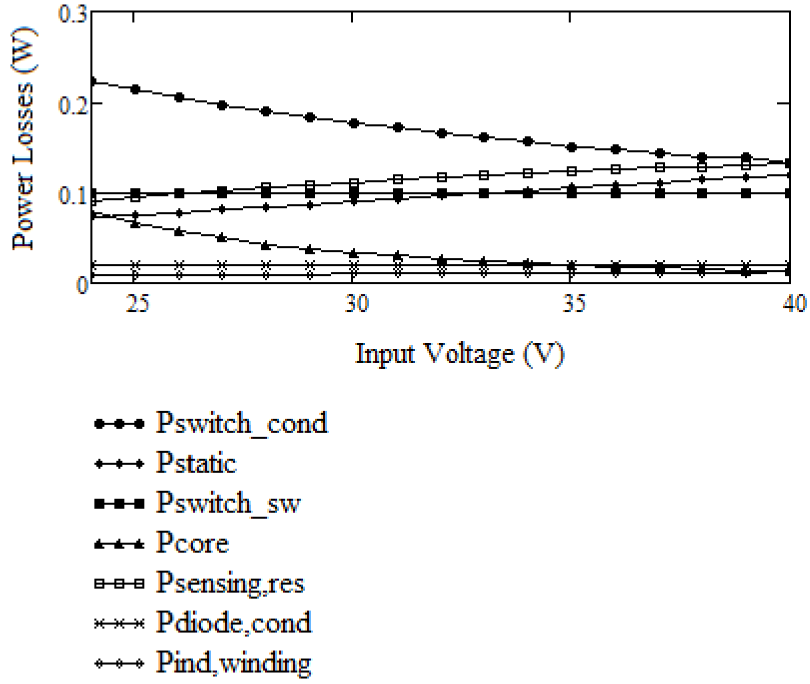


Figure 6.7 The variation of power losses with input voltage.

6.4.b Input Voltage – Circuit Efficiencies

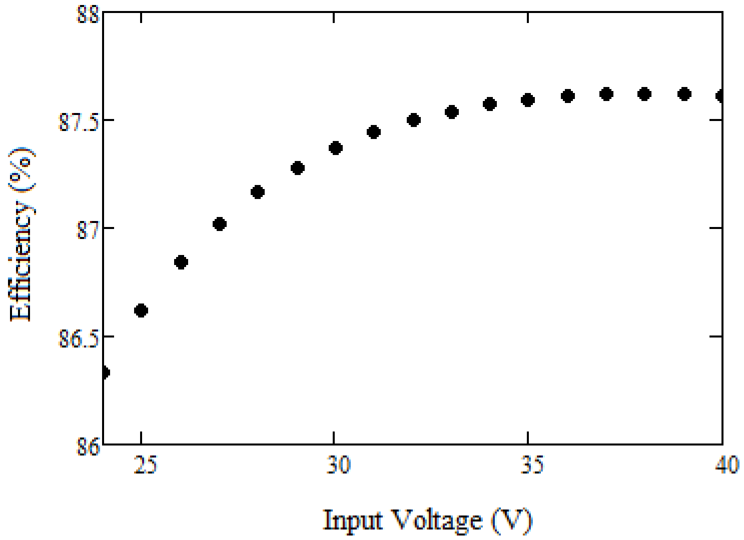


Figure 6.8 The variation of output efficiency with input voltage.

6.5 LED Temperature – LED Currents

Table 6.5 Tabulated values of circuit output efficiency with LED temperature.

V_{in}	T	I_{LED}	V_{LED}	P_{out}	P_{loss}	P_{total}	Efficiency
V	^{0}C	mA	V	V	W	W	%
30	25	320	11.70	3.744	0.529	4.273	87.62
30	30	320	11.60	3.712	0.529	4.241	87.53
30	35	320	11.50	3.680	0.530	4.210	87.41
30	40	320	11.50	3.680	0.531	4.211	87.39
30	45	320	11.40	3.648	0.531	4.179	87.29
30	50	320	11.40	3.648	0.532	4.180	87.27
30	55	320	11.30	3.616	0.533	4.149	87.15
30	60	320	11.20	3.584	0.534	4.118	87.03
30	65	320	11.20	3.584	0.535	4.119	87.01
30	70	320	11.10	3.552	0.535	4.087	86.91
30	75	320	11.10	3.552	0.536	4.088	86.89

6.5.a LED Temperature – Circuit Efficiencies

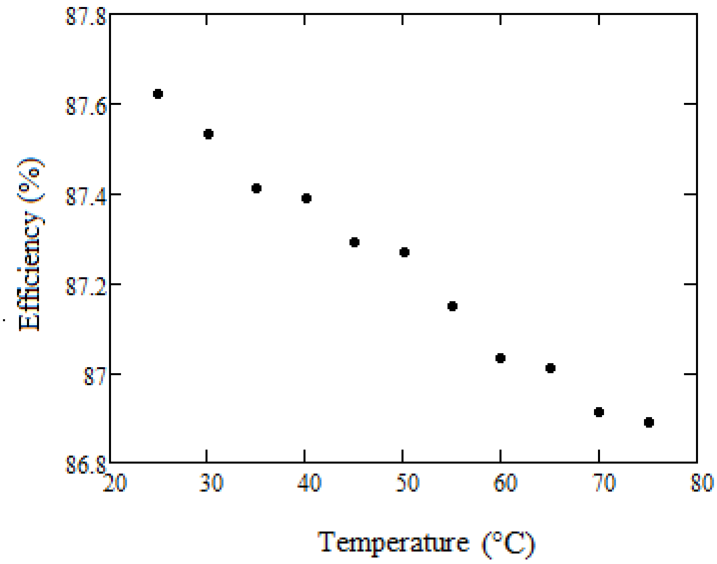


Figure 6.9 The variation of output efficiency with temperature

CHAPTER 7

SUMMARY AND CONCLUSION

In this study, first of all definition and physical formation of light was given in Chapter 1. Also connection of Maxwell equations with electrical field was explained. As light is a type of wave, all wavelengths and visible field wavelengths were explained in the electromagnetic spectrum, and then wavelength values were given. The data shows that the visible field wavelength range is between 0.4 μm and 0.75 μm. Wavelength numerical values of invisible wavelengths such as gamma rays, X rays, ultraviolet, infrared and radio were given.

Illumination, which is the term used for expressing light, was defined. Lux is referred to as unit of illumination and illuminance as the lumen amount in unit surface. Besides; flux, irradiance, intensity and radiance were explained as spatial and spectral definition of illumination in special terms. Types of illumination were expressed in figures. Wavelength - luminous efficiency graph was given. Maximum efficiency is obtained at wavelength of nearly 550 μm. Then, illuminance lux values optimum for different environments were included. The expressions such as luminous, luminous intensity, illuminance and luminance were summarized in the table with their respective units.

Number of fittings necessary for ideal illumination in any room was given with parameter calculations and formulas. The calculation based on room height, work environment and utilization factors was given in details. Calculations were made for ideal illumination.

In Chapter 2, information was provided on Power LEDs. Firstly, working principle of power LED was described. Relationships among conduction band, valance band and parabolic dispersion were given in formulas. Current-voltage characteristics of Power LED was given in a graph, and the relationship between forward bias and reverse bias was explained. How power LEDs emit white light was described. It is possible to emit white light with power LEDs in two ways. They are RGB system and phosphor-based LED. The substances contained in phosphor based LEDs are listed: GaN, InGanN and Ca: YAG. These substances affect efficiency.

Advantages of power LED illumination over other lighting systems are included. They can be listed as high efficiency, colour variations, fitting size, on/off time, cool light source, durability, shock resistance, and focused illumination.

Also disadvantages of power LED illumination are given as high cost of LEDs and reduced performance due to the high temperature. In following chapters, the effect of temperature on circuits designed was analyzed in details. Moreover, since LEDs have electrical polarity, it is a disadvantage that it runs with DC voltage only.

Applications of power LED illumination were given. Large scale projects with LED illumination were pointed out. For instance, LED was first used for street lighting in 2007 in Torraca of Italy. Other examples of LED lighting include shopping malls, factories, etc.

Information was given about other lighting devices than power LEDs. Firstly, incandescent bulbs were mentioned. Those bulbs have a wide colour spectrum, are suitable for wide range voltage, and provide a number of colour options while having quite low efficiency. Working principles of the incandescent bulbs were also explained. Secondly, halogen bulbs were described. Halogen bulbs are more durable than incandescent bulbs with higher efficiency but are more expensive. Thirdly, compact fluorescent bulbs were described. Compact fluorescents are more expensive than incandescent. Lastly, gas-discharge bulbs were explained with their working principle.

After lighting devices were described, they were compared with power LEDs. They have a shorter life span and lumen values than Power LEDs, therefore they are less efficient. Incandescent bulbs have a luminous value of approximately 17lumen/Watt and service life of 1000 hours. Next, fluorescent bulbs are compared with power LEDs. Fluorescent bulbs have a service life of around 1.200 to 20.000 hours and luminous value of 50-67 lumens/Watt. Then efficiency values of bulb types were given in a table. As seen in the table, luminous values of the lighting devices are as follows in a descending order; power LED has a value of 80 -160 lm/W, metal halide bulbs 80 – 125 lm/W, fluorescent bulbs 50 – 80 lm/W, halogen bulbs 25-30 lm/W, and the last one is Edison's light bulbs with a value of 1.4 lm/W. Also power LEDs are compared with other bulbs from the economic aspect. To summarize, LEDs have a service of life nearly 100.000 hours, CFLs have 10.000 hours, and incandescent bulbs 1.200 hours. Total price comparisons of 25 bulbs of each type with equal watts are as follows. Total cost of LEDs is found to be 3.857,40 TL, CFLs 4.037,4 TL, while incandescent bulbs 15.861,6 TL. According to the energy consumption, cost and maintenance costs of all lighting devices above, incandescent bulbs are found the most costly, while LEDs the least costly. This, in turn, indicates the importance of LED lighting.

Chapter 3 is given information about power LED drivers. It is possible to drive LEDs in two ways: voltage limiting and current limiting driver circuits. For LEDs, current limiting is more suitable because it allows driving of LEDs in desired number and it is compliant with the LED structure. LED drivers are divided into two types with linear regulator and switching regulator. Both drivers have subtypes such as buck, boost and buck-boost depending on their aim of use. Of these, buck type has a higher efficiency value as mosfet is contained in this type of driver circuit. The current flow was demonstrated on a template of buck type driver circuit. As for the boost based driver circuits, they are preferable in applications with a higher output voltage than input voltage. As an example, a simple boost type driver circuit was drawn. Lastly, the buck-boost type driver circuit was eligible for adjusting the output voltage as needed. For that, a filter capacitor should be used in both input and output on such circuits. Similarly, a template of the boost-buck driver circuit was given.

In Chapter 4, the driver circuit with a resistant only was designed. On such circuits, a serial resistant was connected to the LEDs to limit the current. Voltage ranging from 24V to 60V was given to the circuit input. The resistance value to limit the circuit current to 320 mA was calculated. 320 mA was taken as a limit since LED luminous reaches the saturation value at 320 mA. When 24V was given to the circuit input, the resistance value to be connected in series was 44 ohm, and output efficiency value was 41.51 %. When an input voltage was given starting with from 24V, serial resistance value was found as 63 ohm at 30 V with output efficiency value of 34.34 %. Serial resistance was calculated as 156 ohm at the time when the input voltage reaches 60 V. In this case, the circuit output efficiency decreases to 16.80 %. It was seen that as input voltage increases, efficiency value decreases. The reason was that the power spent on the resistor increases. After, input voltage circuit total power changes were drawn according to the calculations. The decrease of the efficiency value against the input voltage was shown in the graphs. It was also explained that LED temperature affects the circuit yield. LED temperature changes were made between 25 ^{0}C, standard room temperature, and 75 ^{0}C. Changes in efficiency values were monitored in connection with changing temperature. The circuit efficiency changes by 0.01 % as a consequence of the temperature increase from 25 ^{0}C to 75 ^{0}C. Circuit efficiency calculations were made and graphics were drawn accordingly. The current changes depending on the temperature increase, which was a disadvantage for the LED structure and circuit efficiency. In summary, such circuits have low prices but low efficiency and overheating problem.

In Chapter 5, a driver circuit with a linear regulator was designed. The circuit's input was given 220 volt, then rectified voltage was transferred to the linear regulator. For the linear regulator, LM317 was used. On this circuit also 3 LEDs were connected in series. The NPN transistor and opamp structure integrated into the regulator and working principle of the LM317 was described. The the working principle of the LM317 is to produce the voltage of 1.25 V on the R_1 resistor inserted between the output and the adjust; so, it limits the current. On such a LED driver circuit, input voltage was given as 24V and current was limited to 320 mA. After calculating the circuit losses, circuit efficiency was found as 48.75 %. Then voltage was increased starting from 24 V. Again circuit efficiency was seen to be 39.00% at 30 V and 320mA. When input voltage was increased to 40 V and 50 V, efficiency value was found as 29.25 % and 23.40 %, respectively. However, as input voltage was increased on the circuit, the LM317 was heated excessively. Besides, circuit efficiency was proves lower than required because of excessive loss. The input-output voltage difference falls onto the transistor. In order to see the effect of LED temperature on efficiency without a cooling circuit, LED was heated without using a cooler and then efficiency values were calculated. Calculations show that efficiency changes approximately by 2 % in parallel with change of temperature.

In Chapter 6, a switching driver circuit was designed. MC34063 was used on this circuit due to its eligibility for step-up, step down and voltage converting applications. As it was intended to design 3 LED connected in series, step-down circuit type is found suitable. First of all, a circuit template was prepared, and what devices can be used was investigated. As a result; a transistor, a resistor, a timing capasitor and an inductance was used. The crucial thing here was to calculate the devices' values accurately to optimize the output illumination yield. It was calculated according to datasheet of the device MC34063 and other data obtained through research. As a consequence, the frequency value important for V_{out} , I_L , cycle time, and timing capacitor and timing was calculated, and formulas of V_{ripple} values were calculated for fluctuations. During application, after defining the circuit template, 24 volt input voltage was released, and switching frequency values were given starting from 20 kHz upto 100 kHz. In connection with that, values of Ct, t_{on}/t_{off}, ton, I_{pk}, R_{sc}, L, T_{off}, $t_{on}+t_{off}$ are calculated. The graph of changing device parameters in relation with changing frequency value was drawn. To find out the circuit efficiency, $P_{swicth, cond}$, $P_{sensing, res}$, $P_{diode, cond}$, $P_{ind, winding}$, P_{static} , $P_{swicth, sw,}$ and P_{core} losses were calculated. The circuit efficiency was calculated for various frequency values at 24 V. The frequency values were taken as 20 kHz, 25 kHz, 30 kHz, … , 100 kHz. Output illumination range was calculated as 86. 33 % as a result of 24V input voltage. Under the same circumstances, the lowest value was found as 85.72 % when changing the frequency value only. Graphics regarding output illumination efficiency and circuit loss changes depending on the frequency were created. As seen at first stage of the switching driver circuit design, the best illumination efficiency was reached at frequency of 20 kHz. In the second stage, input voltage changes were applied by stabilizing the frequency at 20 kHz. Accordingly, Ct, t_{on}/t_{off}, ton, I_{pk}, R_{sc}, L, T_{off}, $t_{on}+t_{off}$ values were calculated as in the first stage. Circuit losses such as $P_{swicth, cond}$, $P_{sensing, res}$, $P_{diode, cond}$, $P_{ind, winding}$, P_{static} , $P_{swicth, sw}$, P_{core} are calculated. As a result, circuit illumination efficiency gets 86.33 % at limited current of 320mA with input voltage of 24 V, while it was 87.37 % at the same current with 30 V input voltage. When 40 V was given at input, illumination efficiency hardly changes, which remains at 87.61 %. Graphics were drawn to show circuit losses depending on input voltage. It was indicated in the graph that increases in input voltage results in too little shift in overall circuit efficiency. Also for the effect of the cooling device on this circuit, 30V input voltage was given under temperatures between 25 ^{0}C and 75 ^{0}C, then circuit efficiency changes were calculated. In this case, as input voltage was 30 V, output efficiency comes out as 87.62 % under 25 ^{0}C, 87.53 % under 30 ^{0}C, 87.41 % under 35 ^{0}C, 87.03 % under 60 ^{0}C, and finally 86.89 % under 75 ^{0}C . Temperature change was seen to affect the circuit efficiency by around 0.8 %. Circuit efficiency LED temperature graphic data were obtained. The circuit was realized in the laboratory. By using devices with reasonable market prices, a driver circuit was designed with optimum illumination efficiency with a mc34063 switching regulator.

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APPENDIX

Figure 7.1 Circuit Laboratory Studies 1. Power LEDs.

Figure 7.2 Circuit Laboratory Studies 2. Power LED and PCB.

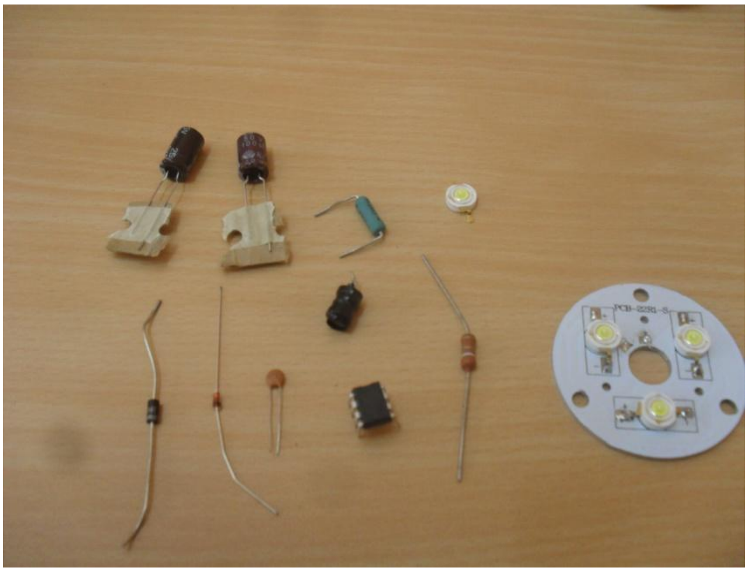

Figure 7.3 Circuit Laboratory Studies 3. The Driver Circuit Devices.

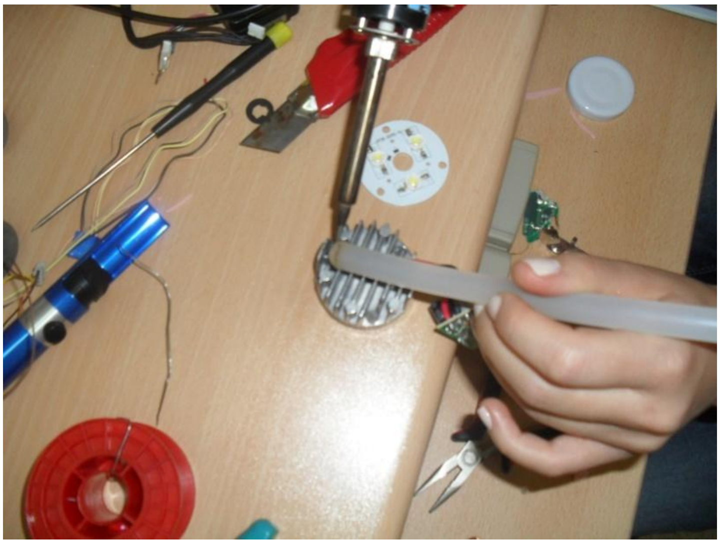

Figure 7.4 Circuit Laboratory Studies 4. The soldering cooling device.

Figure 7.5 Circuit Laboratory Studies 5. The circuit run with 27 V.

Figure 7.6 Circuit Laboratory Studies 6. The circuit run with 32 V.

Figure 7.7 Circuit Laboratory Studies 7. The circuit run with 35 V.

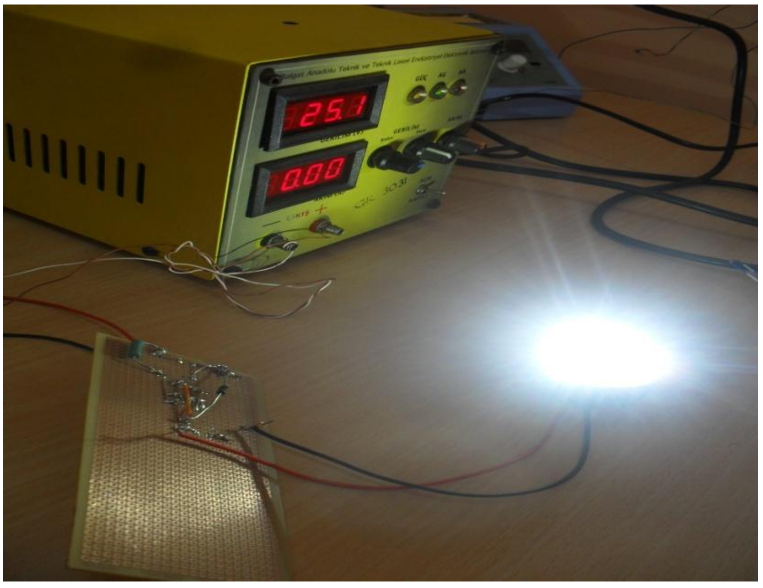

Figure 7.8 Circuit Laboratory Studies 9. The circuit run with 25V and using cooling device.

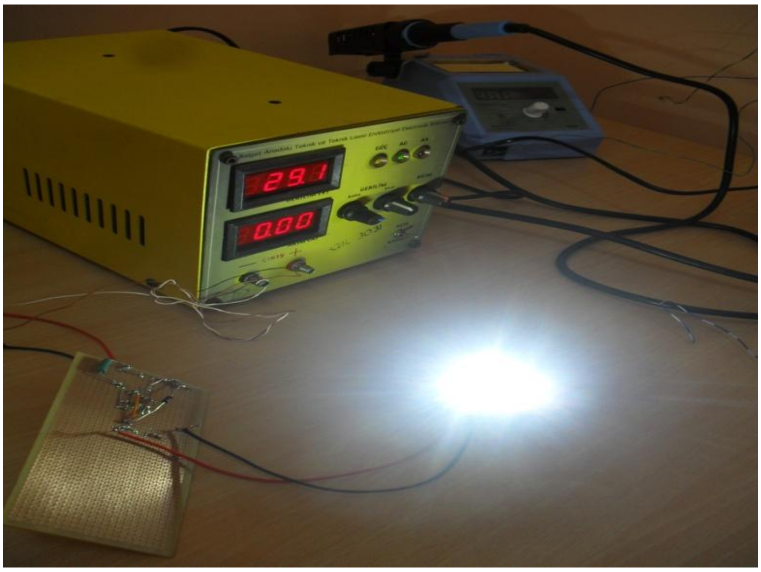

Figure 7.9 Circuit Laboratory Studies 10. The circuit run with 29V and using cooling device.