A thesis on

Design of LED Driver Circuit using Buck and Buck-Boost Converter

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In
Illumination Technology and Design

Submitted by

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DECLARATION

I, Oindrila Saha hereby declare that the thesis entitled **"Design of LED Driver Circuit using Buck and Buck-Boost Converter"**, submitted as a part of my Master of Technology in Illumination Technology and Design is entirely the result of my work and my effort. I have not already obtained any other degree or diploma in my name from Jadavpur University or any other university or college based on this work. I declare that I understood the concept of plagiarism and this thesis has been carried out by me without resorting to plagiarism.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS

1. LED : Light Emitting Diode
2. THD : Total Harmonic Distortion
3. V : Voltage
4. A : Ampere
5. W : Watt
6. Hz : Hertz
7. PWM : Pulse Width Modulation
8. DC : Direct Current
9. AC : Alternating Current
10. DPF : Displacement Power factor
11. MOSFET : Metallic Oxide Silicon Field Effect Transistor
12. CCT : Correlated Color Temperature
13. SCR : Silicon Controlled Rectifier
14. BJT : Bipolar Junction Transistor
15. IGBT : Insulated-gate bipolar transistor
16. DLP : Digital Light Processing
17. LCD : Liquid Crystal Display
18. PF : Power Factor
19. EMI : Electromagnetic interference
20. RGB : Red, Green and Blue
21. KVL : Kirchhoff's Voltage Law

INTRODUCTION

Light is the source of each and every form of life. Beginning from the history of human race it was the most important phenomenon of all to make light more efficient and user-friendly resources. But now the necessity has increased and scientists and engineers have been working together to make light sources more efficient and LEDs have become more popular in the fields of medical science, engineering and so on.[1]

A Light Emitting Diode (LED) is a special type of diode that is used as an Optoelectronic device. It conducts when forward biased, just like a p-n junction diode. However, there is a special feature of this device which is its ability to emit energy in the visible range (visible light) of the electromagnetic spectrum. Now, a major concern is that an LED needs a constant supply, but the supply that we receive is an alternating one. Thus, to convert the AC supply to the required input for an LED (DC), we need a driver circuit. Many a time, an LED is driven using batteries or some controlled devices like micro-controllers. But these have their own disadvantages, like low battery life, etc. The main function of the LED driver is to convert higher voltage, alternating current to low voltage, and direct current.[2]

LEDs require drivers for two purposes:(a)LEDs are designed to run on low voltage (12-24 V), direct current electricity. However, most places supply higher voltage (120-277 V), alternating current electricity. An LED driver rectifies higher voltage, alternating current to low voltage, direct current. (b)LED drivers also protect LEDs from voltage or current fluctuations. A change in voltage could cause a change in the current being supplied to the LEDs. LED light output is proportional to its current supply, and LEDs are rated to operate within a certain current range (measured in amps). Therefore, too much or too little current can cause light output to vary or degrade faster due to higher temperatures within the LED.[3]

This project report deals with the design of an LED driver circuit using buck and buck-boost topology. MATLAB simulations have been performed with LED load being driven by the buck topology as well as buck-boost topology. Various parameters have been measured and compared for both topologies to determine which topology is providing better performance.

Chapter 1 deals with the general discussion on the working principle of LEDs. It consists of a discussion on the various components that a light system requires to function properly. Working principles of LED drivers have also been discussed in this chapter. The advantages, limitations and applications of LED have also been discussed here. Emphasis has been given to the working principle of both the buck driver and buck-boost driver.

Chapter 2 deals with the various parameters of LED drivers which determine if a driver is economically viable for use. Parameters like efficiency, power factor and total harmonic distortion, percent flicker, cost, constant current operation, and protection features have been discussed in this chapter.

Chapter 3 deals with the overall design of the LED drivers. It describes the specification of LED chips used. The configurations and linear model of the LED module have also been discussed. Calculations of both buck driver and buck-boost driver topology parameters have been done in this chapter.

Chapter 4 deals with the Simulink implementation and evaluation of the driver topologies. Comparative analysis based on the various figures of merits has been performed to study the benefits and limitations of both the topologies.

Chapter 5 deals with observation and the future scope of the work on this topic.

LITERATURE REVIEW

In this modern age of energy crisis, efficient lighting design for indoor and outdoor applications, user's requirement is very important. Besides this factor, another main concern is how the lighting design scheme will be effective from an energy point of view and the power quality of the distribution system. To keep the energy consumption by the system to a low level and to maintain the power quality of the distribution system to an acceptable limit, the main concerns are the types of lamps and control gears selected for the lighting installation. After the introduction of the Light Emitting Diode (LED) into the market, it has become a promising alternative to other types of lamps.

LED drivers serve two main purposes; one is to convert higher voltage, alternating current to low voltage, direct current, and the other is to keep the voltage or current flowing through the circuit at its rated level. For the LEDs to be energy efficient, the drivers need to be efficient as well. The driver should be such that it reduces energy losses and improves the power quality. So, a LED driver with improved energy-saving capability becomes somewhat mandatory.

Buck converters are an attractive choice for LED drivers in off-line and in low voltage applications as they can produce a constant LED current at very high efficiencies. A peak current-controlled buck converter can give reasonable LED current variation over a wide range of input and LED voltages and needs no design effort in feedback control design. Coupled with the fact that these converters can be designed to operate at above 90% efficiencies, the buck converter based driver becomes an attractive solution to drive high brightness LEDs.[4]

A boost-buck converter is a single-switch converter, which consists of a cascade of a boost converter followed by a buck converter.The converter can both boost and buck the input voltage. Thus, it is ideal for cases where the output LED string voltage can be either above or below the input voltage during operation. This condition is most common in automotive applications, or when a customer wants a single driver design to cover a wide range of voltage supply and load conditions.One of the advantages of the boost-buck converter is capacitive isolation. The failure of the switching transistor will shorten the input and not affect the output. Thus, the LEDs are protected from failure of the MOSFET.[5]

OBJECTIVE

The aim of this project is to design an LED driver circuits using buck and buck- boost converter topology, design the topologies with suitable component values and then assess the important parameters such as efficiency, percent flicker and cost.

STEPS OF EXECUTION

1. A 8.23 W LED load using various series-parallel combinations is designed.
2. Values of various internal components of both buck driver as well as the buck-boost driver for a lighting load of 8.23 W are calculated.
3. Both LED driver topologies are simulated in MATLAB Simulink.
4. Current and voltage waveforms of 8.23 W LED module when driven by the LED drivers of different topologies at 12 V DC supply (Source being a Solar Cell of 12 V) at different dimming levels are recorded.
5. Efficiency and percent flicker, at different dimming levels for both the topologies are calculated.
6. The recorded parameters are compared for both the topologies.

1 Chapter One

LED Lighting System:Basic Principles and Components

This chapter deals with the general discussion on the working principle of LEDs. It consists of a discussion on the various components that a light system requires to function properly. Working principles of LED drivers have also been discussed in this chapter. The advantages, limitations and applications of LED have also been discussed here. Emphasis has been given to the working principle of both the buck driver and buck-boost driver.

1.1 Working Principle of LED

Light emitting diodes (LEDs) are a widely used standard source of light in lighting equipment. The LEDs are heavily doped p-n junctions. For the operation of the LED, it must be connected to the forward biasing.[6] Due to the forward biasing, the potential barrier between the P and the N region decreases because of the electron-hole pair recombination in the active layer(depletion region). The working principle of the LED can be understood from the energy band gap theory. This theory states that the ability to release photons upon electron-hole pair recombination depends upon the band gap of the semiconductors, i.e., whether the semiconductor has a direct band gap or semiconductor band gap. If the semiconductor materials used in LEDs have a direct band gap, then they will emit photons. The semiconductor materials that have a direct band gap mean that the highest energy level of the valence band lies exactly above the topmost energy level of the valance band and lies exactly below the lowest energy level of the conduction band on the E-M (energy vs momentum) diagram of the energy levels.According to the energy band gap theory, when the electron energy E equals the energy band gap difference

Δ (EV) is released in the form of light photons.[Figure 1].

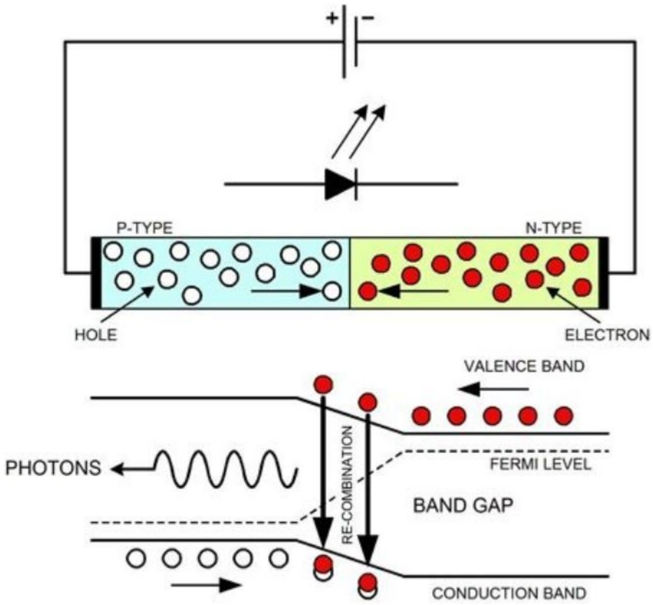

Figure 1: Working Principle of LED

When no voltage is applied across the LED circuit, the electrons and holes in the p-region and the n-region respectively remains stable, but when the voltage is applied to the LED the circuit will be forward biased, hence the electrons present in the N region starts moving towards the holes present in the P region and the electron-hole pair recombination takes place in the active region of the circuit, which is why the active region is also known as the depletion region. As holes are positively charged and electrons are negatively charged the light is emitted by the recombination of the holes and the electrons. The release of the photon is due to the energy differences of the holes and the electron. According to the energy band gap theory, the electrons present in the conduction band have higher energy than the holes in the valence band. The semiconductors materials that are used for the construction of the LEDs have an energy difference between the holes and the electrons equal to the visible light energy range, and when electrons and the holes recombine in the active region, the energy of the electron releases in the form of a photon of visible range. This phenomenon is known as electroluminescence.[Figure 2]

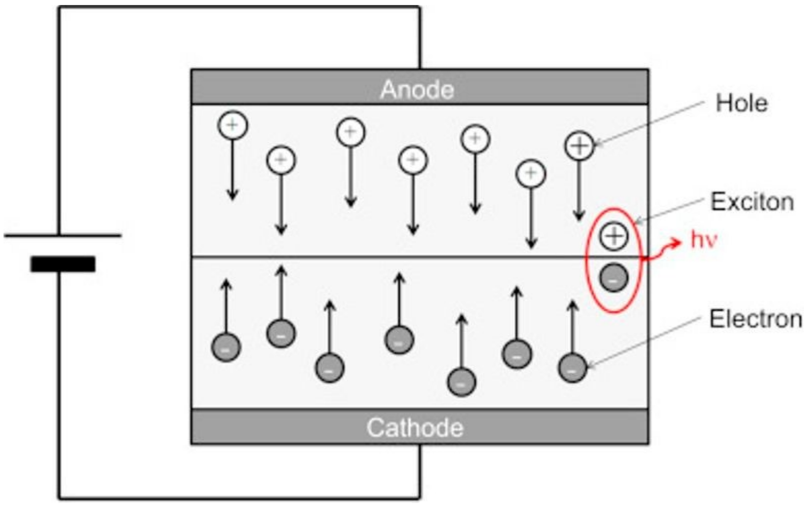

Figure 2: Electroluminescence

The color of an LED is determined by the semiconductor material in use. Aluminium gallium indium phosphide alloys and indium gallium nitride alloys are commonly used. Aluminium alloys are used to obtain red, orange, and yellow light, and indium alloys are used to get green, blue, and white light. Even the slightest of changes in the composition of these alloys change the color of the emitted light.

1.2 LED Specifications

Various types of LEDs are available in the market, each type has its own specifications and datasheet. One should understand the specification of the particular LED before choosing it so that an optimum LED can be selected for the specific purpose.

1. **Electric Current or Voltage Specifications:** LED requires some amount of current to pass through it before emitting the light, the output light intensity of the LED is directly proportional to the forward electric current flowing through it; however, a series resistor is used in the circuit to protect the LED from the passing the excessive electric current through it. One should not connect the LED directly to the power supply because the sudden increase in the electric current can immediately burn out the LED. Each LED has a particular forward voltage drop, which mainly depends upon the semiconductor material used for its construction. Usually, it occurs at the 20 mA forward electric current.

2. **Reverse Voltage:** LEDs cannot tolerate the large reverse voltage. They should always be run below the specified maximum reverse voltage. Running the LED's above this value may lead to its permanent destruction. To protect the LED from this situation, a normal diode can be fitted in the circuits.

3. **Angle of View:** The angle of view is defined as the angle through which the LED spreads its light and it is measured in terms of degrees. Typically, the angle of view of LED is nearly 30 degrees, but some specially designed LED's have the viewing angle up to 140 degrees. The larger will be the angle of view, the more will be the illumination by the LED.

4. **Brightness/Light Intensity:** The intensity of the light emitted by the LED depends upon various factors such as construction material, design of the LED, electric current, and encapsulation of the LED. The brightness of the LED is not an issue if it is being used for indicator purposes; however, brightness is a crucial factor if LED needs to be used for the lighting purpose. The brightness of the LED is measured in terms of lumens(lm) or millicandela (mcd).

5. **LED Colour:** The colour of the LED is also an important parameter for choosing the LED. The colour radiated by the LED depends upon the type of material used for its construction and the forward voltage of the circuit. For example, Gallium phosphide emits green or red colour at 2.2 V, Gallium Arsenide phosphide emits red colour at 2.1 V while yellow colour at 2.2 V, Aluminium Gallium Indium Phosphide (AlInGap) emits amber colour at 2.1 V. Visible LED's that are widely used consist of the larger gap between the valence and the conduction band. The frequency of the photon depends upon the size of the band gap, i.e., the band gap determines the colour of the LED. It is to be noted that we can only observe those photons that lie in the range of visible wavelength. For example, in a Silicon diode, the band gap between the conduction and the valence band is very low due to which the energy emitted by the electrons is very low, hence the frequency of the photons is very low; it lies in the infra-red region, which is not visible to human eyes. The infra-red LEDs may not be employed for lighting purposes, but they are widely used for remote controls and other security systems.

6. **Operational Life:**The intensity of the light does not remain the same all the time, it gradually starts diminishing. The operational life specifications of the LED are usually defined as L70% (time to 70% of the illumination) and L50% (time to 50% of the illumination). Basically, L70 represents the point of time when the illumination of the led

reaches 70% of its original output light. For example, An LED that was producing 10,000 lumens originally, will reduce to 7,000 lumens at some point, and this point in time is called L70. No matter what's the type of LED, the illumination of every LED fades after sometimes, hence the time difference that an LED takes to reach L70 or L50 is an important specification for buyers to choose the best LED.

7. **Efficiency of LED:** The external efficiency of the LED refers to its ability to convert electrical energy into light. It is the ratio of the output light to the input electrical power.

$$\eta_{ext} = \frac{P_{out}}{I_v} \tag{1}$$

The internal efficiency of the LED depends upon the types of layers, structure and quality of the materials used to construct the LED.It is given by,

$$\eta_{int} = \frac{rate\, of\, electron - hole\, pair\, recombination}{Total\, recombination} \tag{2}$$

1.3 Advantages of LED

LEDs are preferred over other light sources due to their various advantages. We will discuss some major points here.[7]

1. One of the prime reasons for using LEDs over other light sources is the efficiency of the LEDs. In the case of incandescent bulbs, to illuminate the light, the filament of the bulb needs to be warmed first, and due to which a large amount of electricity is getting wasted to heat the light bulb. However, in the case of LEDs, maximum electricity is getting used for generating the light, and a minimal amount of heat is produced during the process. This makes the LEDs more cost efficient as they help to cut down the electricity bill.

2. LEDs don't have filaments like other incandescent bulbs that get burned out easily, hence their shelf life is much longer than the conventional bulbs.

3. LEDs have a longer lifetime as compared to the other light sources due to their thermal management properties. LEDs are provided with heat sinks, which absorbs the heat produced by the LEDs and dissipate it outside.

4. LEDs have more efficiency in converting electricity into visible light, hence they give more output than regular light sources.

5. With the rising concern of climatic change, environment conscious people are shifting to the eco-friendly options of light sources. The fluorescent lights and incandescent bulbs use mercury as a crucial part of manufacturing. When these conventional lights source reaches the end of their shelf life, special handling is required to dispose of them. On the other hand, one need not worry about the LED's disposal as they do not cause any harm to the environment.

6. Fluorescent bulbs flicker before they are turned on, on the other hand, LEDs can light up instantly; one need not wait for the warm-up period that is required in the conventional metal halide lamps.

7. LEDs release very little amount of heat and most of the light emitted by the led lies in the visible region. Due to this feature of LEDs, many medical experts have preferred the application of LED to deal with Seasonal Affective Disorder (SAD).

1.4 Limitations of LED

LED's have many advantages over conventional light sources, but there exist certain disadvantages too. These are given below.[8]

1. LEDs do not give the white light directly. The commonly available colours of LEDs are blue, green, and red. To obtain the white light, various LEDs of primary colours (red, blue, and green) are merged together to give the white light, and the other method is coating the LED with the phosphorus layers, which turns the original light colour of LED to white light.

2. The light emitted by LEDs is directional, i.e., LEDs emit light in a particular direction, whereas other light sources such as incandescent bulbs or fluorescent lamps emit light in every direction rather than in a particular direction. Hence, specially designed LED bulbs are needed to spread the light in all directions.

3. LEDs don't have the filament that burns out; however, LEDs face the lumen depreciation, in which the original power output of the LEDs gets lowers over time.

4. The quality of light emitted by the LED is highly dependent upon the operating temperature. High temperature may result in changes in the various parameters of the LED.

1.5 Applications of LED

Some applications of LED are listed below:[9]

1. LED indicators can be commonly seen in various industries, these indicators show the operating status of electronic devices. They are also used in digital watches, calculators, and multi meters.

2. LEDs are used as display panels. It is commonly observed in the stadium displays, dynamic messages signs, and dynamic decorative displays. The lightweight and thin displays are used to displays the schedules charts at the railways and the airports.

3. LEDs are used in the DLP projectors as a light source, and also in the LED television to back lit LCD and in the mobile or laptop displays. The RGB LEDs are used to increase the colour gamut by nearly 45 %. The television screens can be made thinner if LED is being used for the back lighting.

4. LEDs are used in flash lights due to their small size and durability. It is also used in the camera flashes and cameras used in mobile phones as LEDs operates at a low voltage, which is safer than the lightning using the xenon flash lamps, which operates at the voltage of 250 volts or more.

5. LEDs can also be used as photo diodes; hence it is used for the detection and photo emission processes.

6. Many of the machine vision applications, such as barcode scanners, make use of the red LEDs in place of lasers.

7. The light emitted by the LED can be easily modulated, due to which they are used in the free space optics communications and optical fibre. Infra-red LEDs are used in the remote controls of the television sets.

8. LEDs find their applications in biological systems too. LEDs are used as the grow light to enhance the photosynthesis process in plants. UV LEDs are used for the sterilization process to kill the viruses and bacteria present in the water.

9. LEDs also find their applications in temporary uses, for example, glow sticks, led art or throwies. Throwies are small LED devices that are used in various types of street art.

1.6 Components of LED Lighting System

There are four main parts of a LED Lamp[Figure 3]:

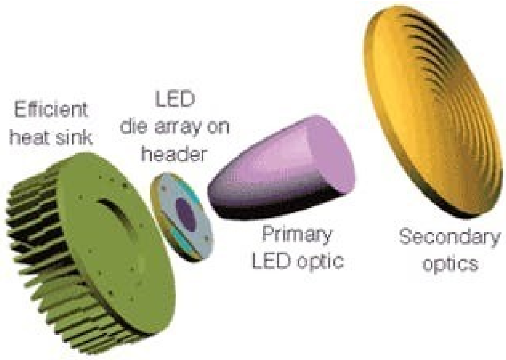

Figure 3: Components of a LED lighting system

1. **LED chip:** This is responsible for producing light when an electric current pass through it. It is made up of semiconductor materials like aluminium gallium indium phosphide alloys and indium gallium nitride and depending on the material produces a different color of light. These are connected in various series-parallel combinations to get the desired illumination levels.[Figure 4]

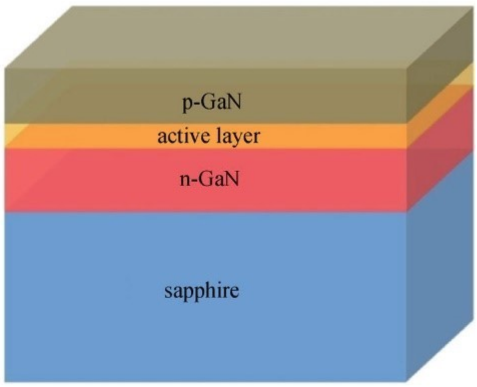

Figure 4: Schematic diagram of a LED chip

2. **LED driver:**It regulates the current flowing through the LED, similar to a ballast in a compact fluorescent light. LED drivers can be internal or external. LED Light output is proportional to its current and any slight variation in the current can result in unacceptable changes in light output. So, the LED driver is a key component of the light output and greatly impacts the lamp life of the LED.

3. **Heat sink:**LEDs generate internal heat within the junction. High temperatures near the LED junction affect the short term and long term life and affect the LED performance. Heat must be removed from the LED chip to maintain its light output, life, and color. Short term effects of improper heat sinking include lower light output, and also a wavelength color shift, while the long term effects include a lower lamp life. The heat sink is essential for removing heat which is removed through convection (by air) or by conduction (by contact). Aluminium is the ubiquitous choice of material for LED heat sinks.[Figure5]

Figure 5: Aluminium heat sink for LED lamp

4. **Optics:**It is also an important component of an LED lamp, which has multi level optics. The Primary Optics is built directly on top of the LED chip. The Secondary Optic collects and redistributes the light in the LED lamp.

1.7 LED Driver

A LED driver is an electronic device that regulates the power of an LED or a string (or strings) of LEDs. Led driver changes the power supply to a specific voltage current to drive the LED voltage converter. In general, the input of the LED driver includes the high voltage power frequency AC (i.e., the city electricity), the low voltage DC, the high voltage DC, the low voltage and high-frequency AC (such as the output of the electronic transformer).[10] The output of LED driver power is mostly a constant current source that can change voltage with the change of LED forward voltage drop. The core components of the LED power supply include switch controller, inductor, switch component (MOSFET), feedback resistor, input filter device, output filter and so on. According to the requirements of different occasions, there must be input over-voltage protection circuit, input under-voltage protection circuit, LED open circuit protection, over-current protection circuit and so on.[Figure 6]

Figure 6: LED Driver

The LED driver can be of different types:[11]

- **Isolated LED driver**It is suitable for AC fed application.Here,usually flyback converter is used.Also, power factor improvement is possible here.It provides isolation between source side and load side by a pulse transformer.[Figure 7]

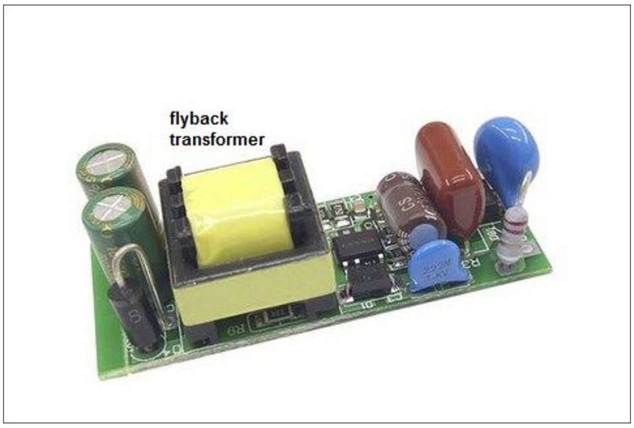

Figure 7: A typical isolated LED driver

- **Non- Isolated LED driver:**It is suitable for DC fed application.Here,usually buck converter is used.Power factor improvement is not possible here.It provides no isolation between source side and load side by a pulse transformer.It is not recommended for high power application. [Figure 8]

Figure 8: A typical non-isolated LED driver

Depending on the operations, LED drivers can be of two types:

- **Constant current LED driver:**Constant-current drivers power LEDs that require a fixed output current and a range of output voltages. There will be only one output current specified, labelled in amps or milliamps, along with a range of voltages that will vary depending on the load (wattage) of the LED. In the example below to the left, the current output is 700 mA, and the output voltage range is 4-13 V DC.

- **Constant voltage LED driver:**Constant-voltage drivers power LEDs that require a fixed output voltage with a maximum output current. In these LEDs, the current is already regulated, either by simple resistors or an internal constant-current driver, within the LED module. These LEDs require one stable voltage, usually 12 V DC or 24 V DC

1.7.1 Buck Driver

A buck driver is based on the principle of buck converter or a step-down DC to DC converter. For a DC–DC converter, input and output voltages are both DC. It uses a power semiconductor device as a switch to turn on and off the DC supply to the load. The switching action can be implemented by a BJT, a MOSFET, or an IGBT.[12] [Figure 9] shows a simplified block diagram of a buck converter that accepts a DC input and uses pulse-width modulation (PWM) of switching frequency to control the switch. An external diode, together with external inductor and output capacitor, produces the regulated DC output. Buck, or step down converters produce an average output voltage lower than the input source voltage.[13]

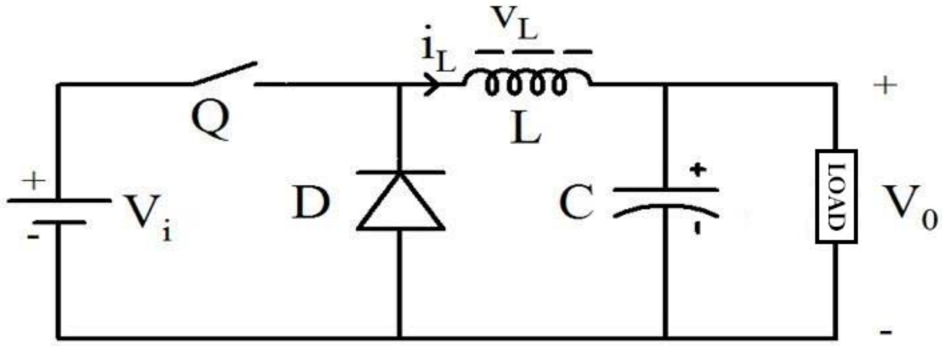

Figure 9: Buck Converter

Buck Driver Operation :

Mode 1: The operation of a buck converter happens in two modes. The first mode is when switch Q close, and the second one is when switch Q open. When switch Q closes, current flows from the supply voltage V_i through the inductor and into the load, charging the inductor by increasing its magnetic field and increasing V_o. Diode D will be on reverse bias, thus blocking the path for current.An inductor reduces ripple in current passing through it and the output voltage would contain less ripple content since the current through the load is the same as that of the inductor. At the same time, the current through the inductor increases and the energy stored in the inductor increases. When V_o reaches the desired value, switch Q is open and diode D is turned on. [Figure 10] shows this mode.[14]

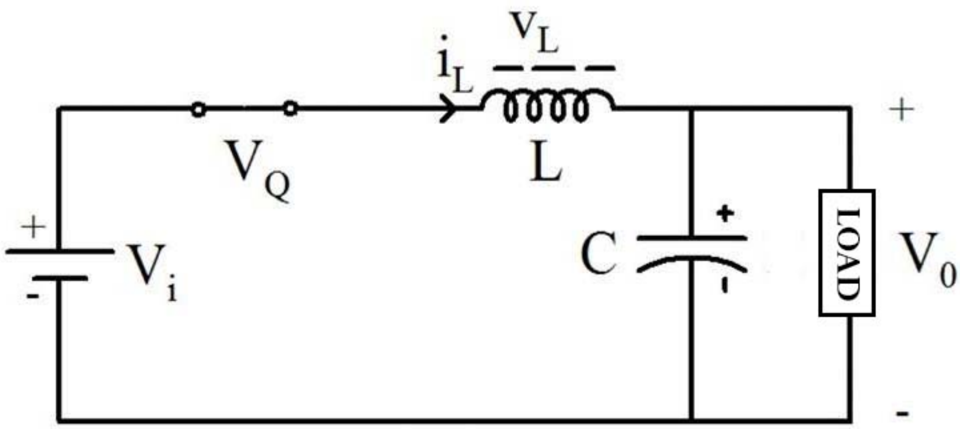

Figure 10: Switch Q closed

Mode 2: When the switch Q opens, the inductor acts as a source and maintains the current through the load. During this period, the energy stored in the inductor decreases and its current falls.[15] Current continues to flow in the inductor through the diode D as the magnetic field collapses and the inductor discharges. Before the inductor completely discharges, diode D is open and Q is closed and the cycle repeats. It is important that there is continuous conduction through the load for this circuit.[Figure 11] shows this mode.

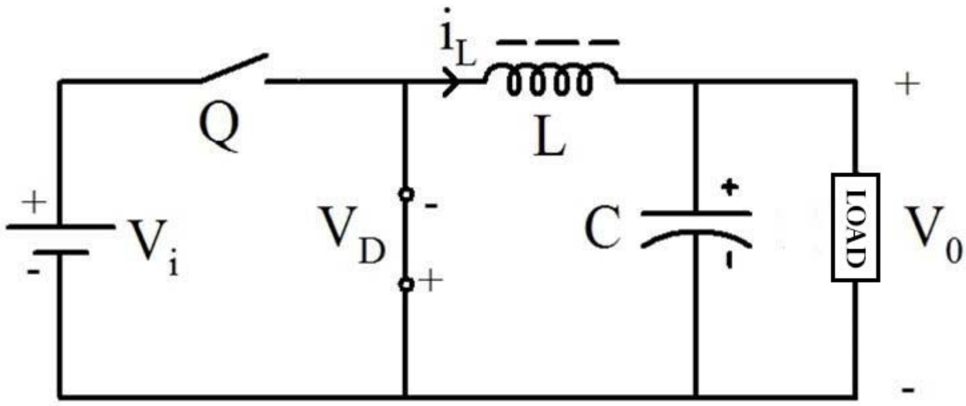

Figure 11: Switch Q open

Buck Driver Duty Cycle :

The ratio of output voltage, V_out to input voltage, V_in can be adjusted by varying the duty cycle of switch Q. The longer Q is turned on, the greater V_out will be. The duty cycle of Q is usually called the converter's duty cycle. If the switches and the inductor are lossless, V_in is converted to V_out with no loss of power and the conversion is 100% efficient. [Figure 12] shows variation of duty cycle. Duty cycle is always being presented in percentage value. A 60% duty cycle means the power is on 60% of the time and off 40% of the time.

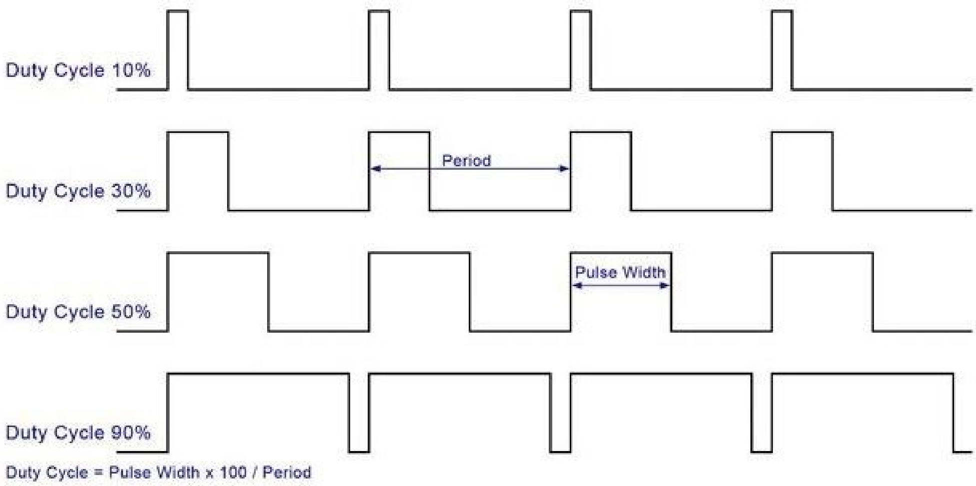

Figure 12: Duty Cycle

1.7.2 Buck-Boost Driver

A buck-boost driver is based on the principle of buck-boost converter.In buck-boost converter, the output voltage may be less or more than the input voltage, hence the name buck-boost converter. In this converter, the output voltage polarity is opposite to that of the input voltage. As a result, this converter is also known as inverting converter.[16]
The circuit diagram of buck-boost converter is shown in [Figure 13]. It is seen from the figure that Switch Q is connected in series, as in a buck converter. Inductor L is shown connected across the input terminals. Diode D is connected like a boost converter but with reversed polarity.[17]

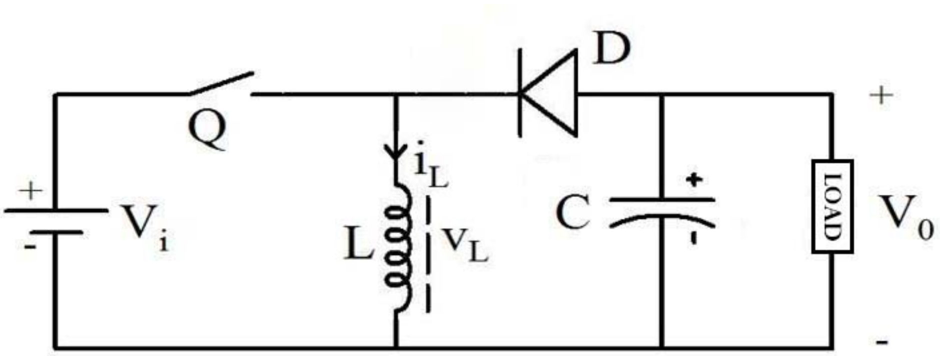

Figure 13: Buck-Boost Converter

Buck-Boost Driver Operation :

The circuit operation can be divided into two modes:

Mode 1: During this mode, Switch Q, is closed at t=0, diode D is reverse biased by Voltage V_i, giving the equivalent circuit. [Figure 14]During this mode, inductor L is directly connected across voltage source V_i, therefore input current is equal to i_L. Thus the inductor stores energy from the input. Also, $v_L = V_i$.[18]

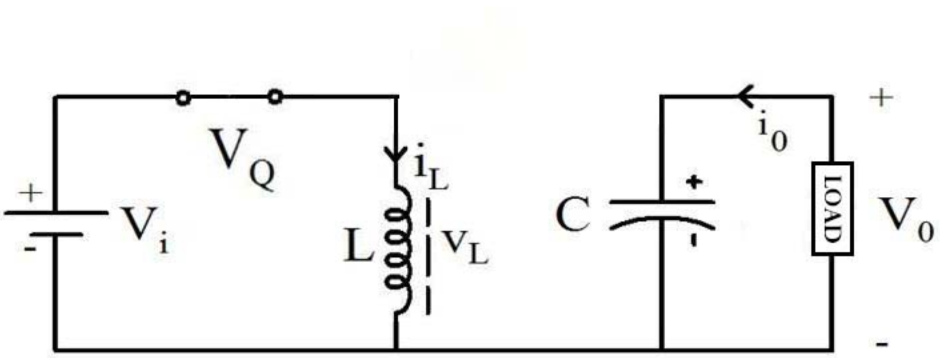

Figure 14: Switch Q closed

Mode 2: At t=T_on, switch Q is opened, as a result inductor current $i_L$begins to flow through L,C, Load and diode D,[Figure 15.In this mode,no energy is supplied by the input source V_i. However, energy stored in inductor L, is now transferred to the load, as a consequence, inductor current falls until switch Q is turned on again at t=T, for the next cycle.In the equivalent circuit [Figure 15], by KVL, we can say that, v_L = -V_o.

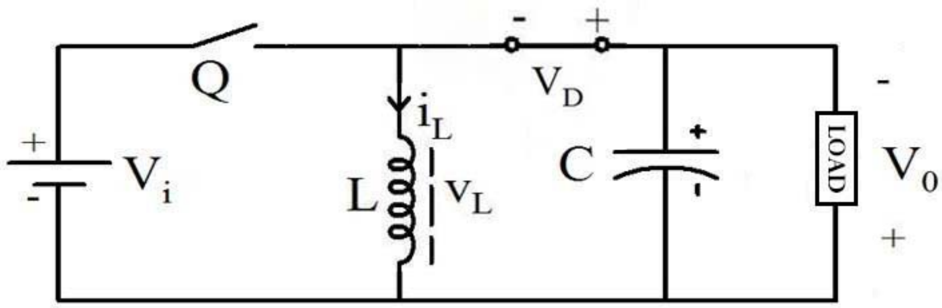

Figure 15: Switch Q open

2 Chapter Two

LED Driver: Figure of Merits

This chapter deals with the various parameters of LED drivers which determines if a driver is economically viable for use. Parameters like efficiency, power factor and total harmonic distortion, percent flicker, cost, constant current operation, and protection features have been discussed in this chapter.

The figure of merits the new alternative topology must outperform or perform at the same level as the traditional driver are as follows:

- Efficiency
- Power Factor and Total Harmonic Distortion (THD)
- Percent Flicker
- Constant Current Operation
- Protection Features
- Cost

2.1 Efficiency

The efficiency of the LED driver is given by the ratio of energy emitted by the driver to the power it consumes from the electric line. The LED driver contains many active and passive components. The active components include a transistor, integrated circuit, SCR, MOSFET, etc. Active components need power for their operation They can produce power gain and amplify signals. Due to the existence of parasitic resistance of the components like PCB, and cable, there is power loss occurring on the path through which the current goes. Unlike active components, passive components are those part of the device that does not need the extra control signal to operate, including diodes, transformers, capacitors, inductors, and resistors. So passive component loss refers to energy loss occurring in the passive components of the circuit. All these energy losses add up to reduce the overall efficiency of the LED driver. The efficiency of the drivers can be increased if the value of the components required in manufacturing is reduced to an extent without reducing its performance capabilities. Efficiency is one of the key factors in determining the LED driver to use in lighting as we move towards more energy-efficient lighting technologies.

$$LED\ Driver\ Efficiency = \frac{Input\ Power}{Output\ Power} \tag{3}$$

The need for high-efficiency LED drivers is due for the following reasons:

- Energy and Cost Saving: High-efficiency LED drivers reduces operational cost. They require less input energy to provide the needed luminous output. Hence results in a low cost of power utility bills.
- Increased Product Lifespan: The higher the driver's efficiency, the lesser the heat it dissipates, and the longer the system's life.

2.2 Power Factor and Total Harmonic Distortion

Despite LED lighting's high luminous efficacy power quality of LED lighting has been a concern. Power Factor (PF) and Total Harmonic Distortion (THD) are key performance parameters that can limit the wide acceptance of LED lighting in the marketplace. Power quality for any AC lamp indicates how the lamp draws current when supplied with sinusoidal voltage from the AC mains, which in turn is non linear for LEDs. As a consequence of this non linear behaviour, existing LED lighting solutions to exhibit poor power quality scores in terms of both power factor ("PF") and total harmonic distortion ("THD").

$$Power\ Factor = \frac{True\ Power}{Apparent\ Power} \tag{4}$$

Power factor is defined as the ratio of the real power absorbed by the load to the apparent power flowing in the circuit.The power factor formula can be expressed as: True power is the actual power available to perform real work. Poor power factor means that power is being used inefficiently. [Figure 16] LEDs running on a lower power factor draw more current than when it is running at a higher power factor. Hence, for the same wattage demand, the input power required by the LED with a higher PF will be less than that with the lower PF. And since output remains the same the efficiency will be higher in the case of high-power factor as input power required is less. LED lighting systems are driven by electronic LED drivers which have an inherently capacitive electrical characteristic. These drivers have an integrated active power factor corrector, resulting in a high-power factor > 0.95 at full load.

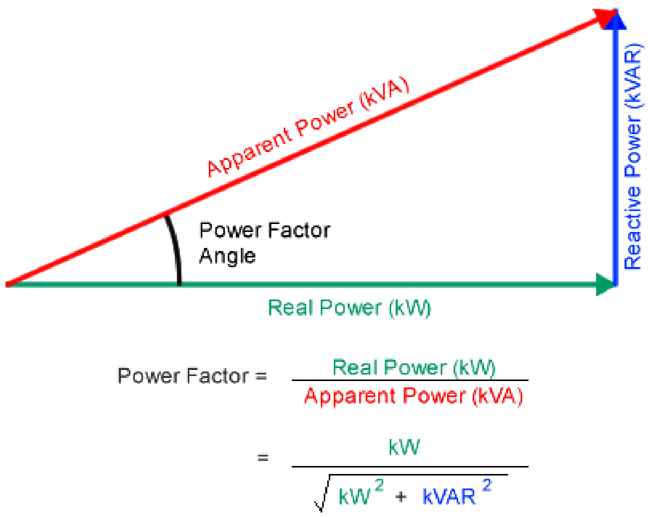

Figure 16: Power Triangle and Power Factor

THD is a numeric representation of distortion in the current waveform relative to the sinusoidal voltage waveform on the AC mains. Distortion indicates how much harmonic current is flowing in the power lines. Harmonics are unwanted currents having frequency as multiples of the fundamental line frequency (e.g., 50 or 60 Hz). Harmonic currents can create additional voltage and power losses in the transmission lines, heat transformers, and capacitors, resonate with power factor correction capacitors, and/or overload neutral conductors. Uncontrolled harmonic currents in commercial facilities may lead to outages and even fires.

Total Harmonic Distortion is given by the equations:

$$Distortion\ Power\ Factor = \frac{1}{\sqrt{1 + THD_i^{\ 2}}} = \frac{I_{1rms}}{I_{rms}} \tag{5}$$

where,
THD_i is the total harmonic distortion of the load current.
I_{1rms} is the baseband component of the current.
I_{rms} is the total current, and both are expressed by root mean square.

The above definition assumes the voltage to be a sine wave without distortion. The total power factor can be acquired by multiplying the distortion power factor by the displacement power factor, which is also called the real power factor or power factor.

$$Power\ Factor = DPF * \frac{I_{1rms}}{I_{rms}} \tag{6}$$

It can be noticed that THD is inversely related to the power factor. So, an increase in power factor decreases the value of THD, thus reducing harmonics. As a result, the Power Quality is improved. This can be achieved by using a proper LED driver, that has power factor correction features to increase the power factor and mitigate the problem of developing harmonics.

2.3 Percent Flicker

The term percent flicker was given by Illuminating Engineering Society (IES). It is defined as the relative measure of the cyclic variation in the amplitude of light. The range has been given as 0-100%. The lower the percent flicker, the less significant the flicker.Most commonly it is the result of the varying AC supplied to the light, which, after rectification (converting AC to DC), oscillates at twice the mains frequency (100 Hz or 120 Hz). Other potential causes include transformer incompatibility, dimmer compatibility, and the high frequency ripple controls superimposed onto the main power signals of residences participating in load control programs.The perceptibility of flicker can be subjective, especially at frequencies above 75 Hz.Even with flicker indexes up to 0.5, flicker was not immediately noticeable, however for those particularly sensitive to flicker, effects could potentially manifest in eye strain and headaches if the light is used over prolonged periods. Individuals concerned about stroboscopic effects should use LED products with percent flickers of no more than 10% for 60 Hz line frequency, or 8% for 50 Hz AC mains.

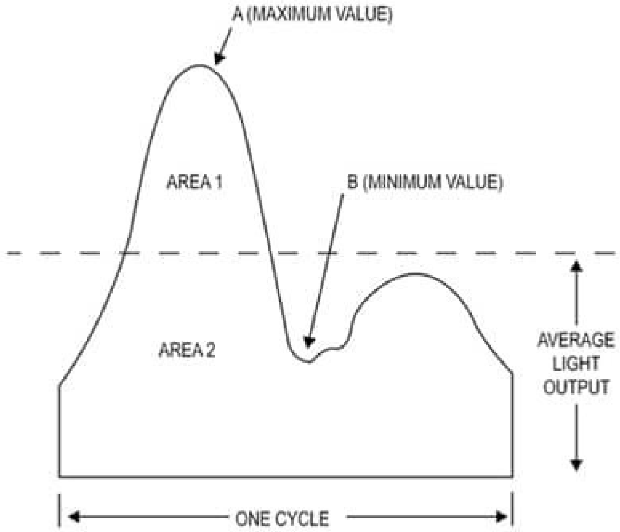

Figure 17: Schematic diagram of Percent Flicker

From the given diagram [Figure 17] percent flicker can be calculated as:

$$Percent\ Flicker = 100 * \frac{(A - B)}{(A + B)} \tag{7}$$

LED drivers with a constant current mode of operation can reduce percent flicker in LEDs. Input and output filtering in LED drivers reduce flicker further.So,choosing a good quality high frequency switching LED driver that minimizes the AC component in the voltage and current ripples at the output which in turn will limit the modulation depth of the LED's flicker becomes important.

2.4 Constant Current Operation

LEDs are current driven devices instead of voltage driven. The lumen output of the LED is proportional to the forward current passing through the LED. The higher the current is, the brighter the LED. However, a greater amount of heat is generated at the semiconductor junction region. This is because LEDs convert only around 50% of the energy into light and the remaining portion of the energy is released as heat. If the maximum allowable junction temperature is exceeded, high heat flux can lead to irreversible damage to the LED as well as reduce the optical power of the LED when the temperature is increased. So, limiting the current beyond a limit becomes mandatory. An LED or an LED module that is connected to a constant voltage LED driver ultimately needs a current limiting device to regulate the current. This device can cause power loss and generate an additional thermal load. As a result, power efficiency is reduced and the LEDs becomes susceptible to high thermal stress, especially when current limiting is done using inefficient linear regulators or resistors. However, in a constant current LED driver no additional current limiting devices are required to limit the current to the LED below its maximum rated current. Constant current regulation in drivers ensures the LED module delivers consistent, non-fluctuating light output. Thus, a good quality LED driver should be current controlled in nature. It increases the efficiency of the lamp, does not need the use of the current limiting device, and also gives an added dimming control capability to the user.

2.5 Protection Features

All LED drivers need various protections to prevent failures to protect the system where power suppliers are utilized. There are many types of protections related to voltage, thermal and current which improve the reliability and functionality of LED drivers.The protection scheme for LED driver can be depicted in the [Figure 18].

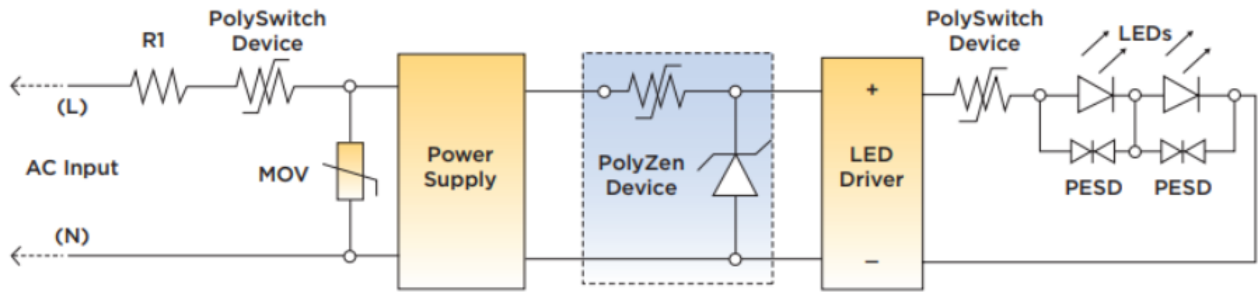

Figure 18: Protection scheme for LED Driver inputs and outputs

A good LED driver must have the following protections:

- Internal Over-temperature protection
- External Over-temperature protection
- Over current protection
- Short circuit protection
- Over-voltage protection
- Input surge (Lightning) protection

2.6 Cost of the Driver

The major driver for LED Driver Market is the growing demand for LED in lighting applications such as retail outlets, and office complexes, and growing usage within the residential lighting application for households. The government is taking initiatives for radiant bulbs for power-efficient lighting and high-quality picture images, provided by the LED manufacturer. In addition to that, LED performance and robustness is driving the market growth of LED driver. For the large-scale adoption of LED drivers, the cost of drivers should be low. However, low cost may restrict the quality and functionality of the LED drivers. So, a balance should be struck between cost and quality. Depending on the use case of the LED bulbs a balance is to be achieved without compromising the basic requirements of the driver. A good LED driver thus should be economically viable for that particular use case.

2.7 Figure of Merits under consideration

In this paper, we will be analysing a few of the parameters that have been discussed. The parameters that have been evaluated are:

- Efficiency
- Percent Flicker
- Cost

Other parameters are beyond the scope of this paper. MATLAB simulations have been conducted for both topologies to calculate and compare the values of the different figures of merits to provide a conclusive result.

3 Chapter Three

Design of LED Driver

It deals with the overall design of the LED drivers. It describes the specification of LED chips used. The configurations and linear model of the LED module have also been discussed. Calculations of both buck driver and buck-boost driver topology parameters have been done in this chapter.

3.1 Specification of LED Chip

Table 1 depicts the LED chip specifications: [19]

Table 1: LED Chip Specifications

Parameters	Values
Rated Voltage	3.65 V at 25 mA
Threshold Voltage	3.11 V
Dynamic Resistance	21.85 Ω
Wattage	0.09 W
Nominal CCT	5650 K, Cool White
Luminous flux	320 Lumens
Typical viewing angle	120°

3.2 Design of LED Module

For the experiment, a 8.23 W LED module has been considered. The LED module has been designed with 3 LED chips in series and such 30 such strings have been taken in parallel (i.e. N=3, M=30), as shown in [Figure 19]. The rated voltage of the module is 10.97 V and the rated current is 0.75 A.

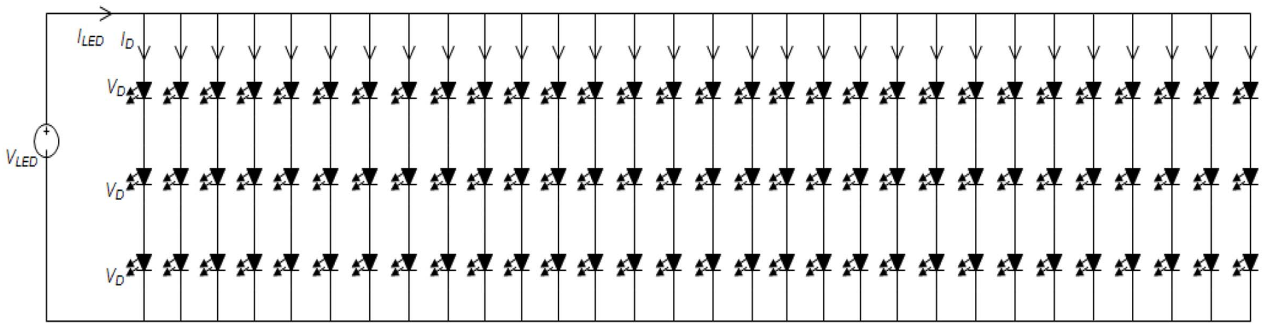

Figure 19: The LED Module

The linear model of LED has been considered to consist of a threshold voltage and dynamic resistance in series as shown in [Figure 20]

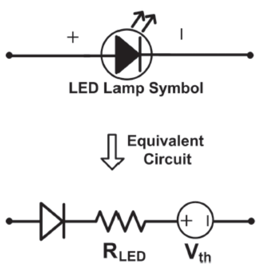

Figure 20: Linear Model of LED

Linear Model of an LED Chip

$$V_D = V_{FD} + I_D * R_D \tag{8}$$

where,

V_D = Forward Voltage

I_D = Forward Current

V_{FD} = Threshold Voltage

R_D = Dynamic Resistance

Further modification of the linear module for N*M LED module[19]:[Figure19]

$$V_{LED} = N * V_{FD} + (\frac{N}{M}) * I_{LED} * R_D \tag{9}$$

where,

N = Number of series connected lED chips

M = Number of parallel strings

3.3 Estimation of Buck Driver Parameters

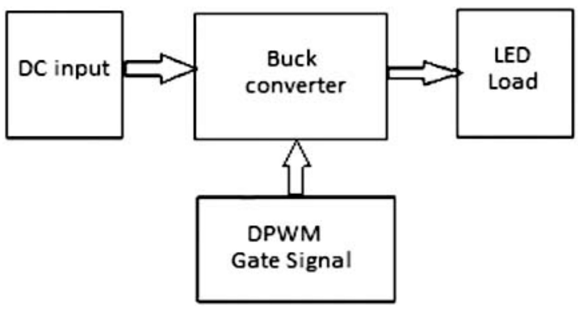

Figure 21: Block Diagram of Buck Driver

3.3.1 Power circuit model:

It is responsible for providing power to the LED module. It consists of an EMI filter to decrease the ripple content in the input current. The design parameters of the buck converter are the switching frequency and duty cycle of the MOSFET switch.[20] The switching frequency has been taken as 60 kHz and the maximum value of duty cycle is 0.92.

The Duty cycle, D of buck driver is given as :

$$D = \frac{V_o}{V_s} \tag{10}$$

where,
V_o = Output Voltage
V_s = Supply Voltage

The value of inductance can be calculated from the below equation:

$$L = \frac{D * V_s * (1 - D)}{f * \Delta I} \tag{11}$$

where,
L = Inductance value
D = Duty Cycle
f = Switching frequency
ΔI = Ripple current (considered 5% of output current)

The capacitance value can be calculated as:

$$C = \frac{\Delta I}{8 * f * \Delta V} \tag{12}$$

where,
C = Inductance value
f = Switching frequency
ΔI = Ripple current (considered 5% of output current)
ΔV = Ripple voltage (considered 2% of output voltage)

3.3.2 Control circuit model:

The LED driver model is current regulated. Here the open loop simulated buck driver is considered. The switching frequency and the duty cycle are fed as the input to the pulse generator which in turn provides the required gate pulse to the MOSFET. On receiving the pulse, the MOSFET becomes ON and as a result, the output voltage starts to build up. The current starts to flow once the output voltage of the driver is greater than the threshold voltage of the LED module.
The estimated values of buck driver parameters are:

Table 2: Design Parameters of the Buck Driver

Parameters	Values
Supply voltage	12 V
Inductance	300 μH
Capacitance	470 μF
Resistance	2 Ω
Maximum duty cycle	0.92

3.4 Estimation of Buck-Boost Driver Parameters

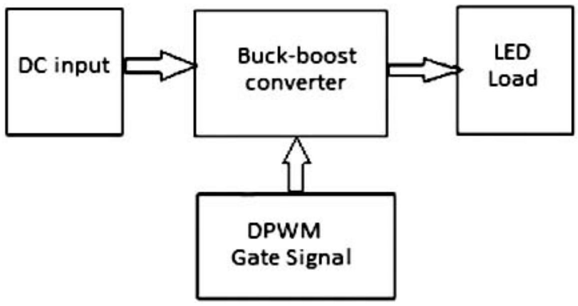

Figure 22: Block Diagram of buck-boost Driver

3.4.1 Power circuit model:

It is responsible for providing power to the LED module.It consists of an EMI filter to decrease the ripple content in the input current. The design parameters of the buck-boost converter are the switching frequency and duty cycle of the MOSFET switch.[21] The switching frequency has been taken as 60 kHz and the maximum value of duty cycle is 0.48.

The Duty cycle, D of buck-boost driver is given as :

$$V_o = V_s * (\frac{D}{1-D}) \tag{13}$$

where,
V_o = Output Voltage
V_s = Supply Voltage

The value of inductance can be calculated from the below equation:

$$L = \frac{D * V_s}{f * \Delta I} \tag{14}$$

where,
L = Inductance value
D = Duty Cycle
V_s = Supply Voltage
f = Switching frequency
ΔI = Ripple current (considered 5% of output current)

The capacitance value can be calculated as:

$$C = \frac{D * I_o}{f * \Delta V} \tag{15}$$

where,
C = Inductance value
f = Switching frequency

D = Duty Cycle
I_o = Ripple current (considered 5% of output current)
ΔV = Ripple voltage (considered 2% of output voltage)

3.4.2 Control circuit model:

The LED driver model is current regulated. Here the open loop simulated buck-boost driver is considered. The switching frequency and the duty cycle are fed as the input to the pulse generator which in turn provides the required gate pulse to the MOSFET. On receiving the pulse, the MOSFET becomes ON and as a result, the output voltage starts to build up. The current starts to flow once the output voltage of the driver is greater than the threshold voltage of the LED module.
The estimated values of buck-boost driver parameters are:

Table 3: Design Parameters of the Buck-Boost Driver

Parameters	Values
Supply voltage	12 V
Inductance	2.56 mH
Capacitance	470 μF
Resistance	0.1 Ω
Maximum duty cycle	0.48

4 Chapter Four

Simulink Implementation and Evaluation of the drivers

This chapter deals with the Simulink implementation and evaluation of the driver topologies. Comparative analysis based on the various figure of merits has been performed to study the benefits and limitations of both the topologies.

4.1 Buck Driver

The Buck driver is simulated using MATLAB Simulink at different load conditions. The values of various parameters are evaluated at different load conditions. Considering here [Figure 23].

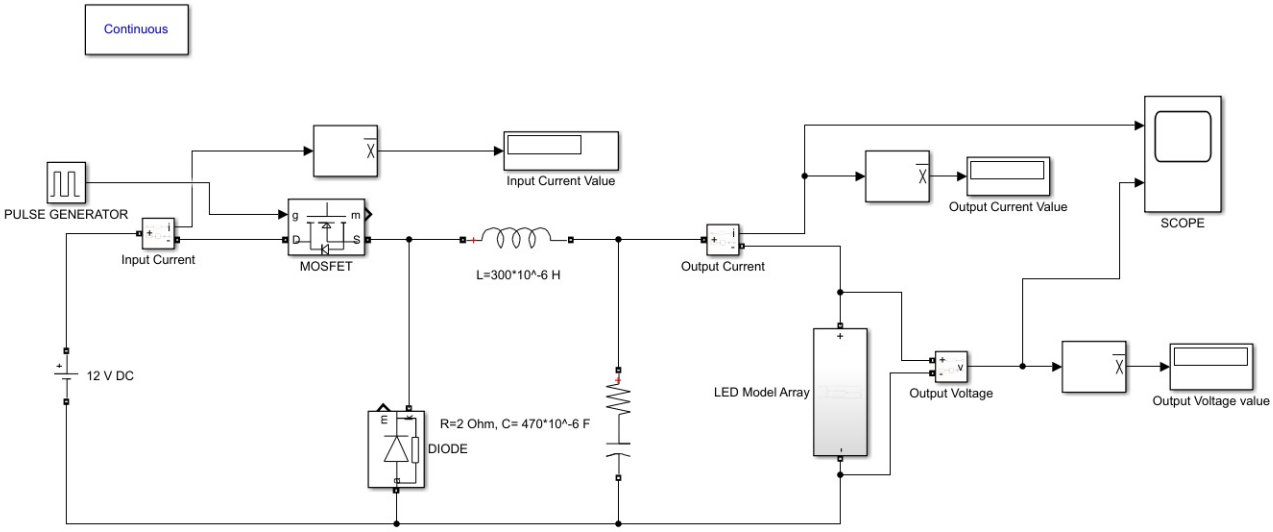

Figure 23: Simulated model of the Buck LED driver

- **At Full load:** The input voltage is 12 V and the input current is 0.6903 A. The reference current is set as full load current i.e., 0.75 A. Following the linear model of LED, the output voltage is thereby 10.97 V. Thus, the duty cycle, D should be 92%. The duty cycle is adjusted to 92.4 % to get the output current as 0.7451 A and the output voltage as 10.96 V. The output power is 8.23 W. The calculated values at this condition are:

  Efficiency: 98.58%

  Percent Flicker: 1.54%

  The output voltage and output current at full load is depicted in the [Figure 24].

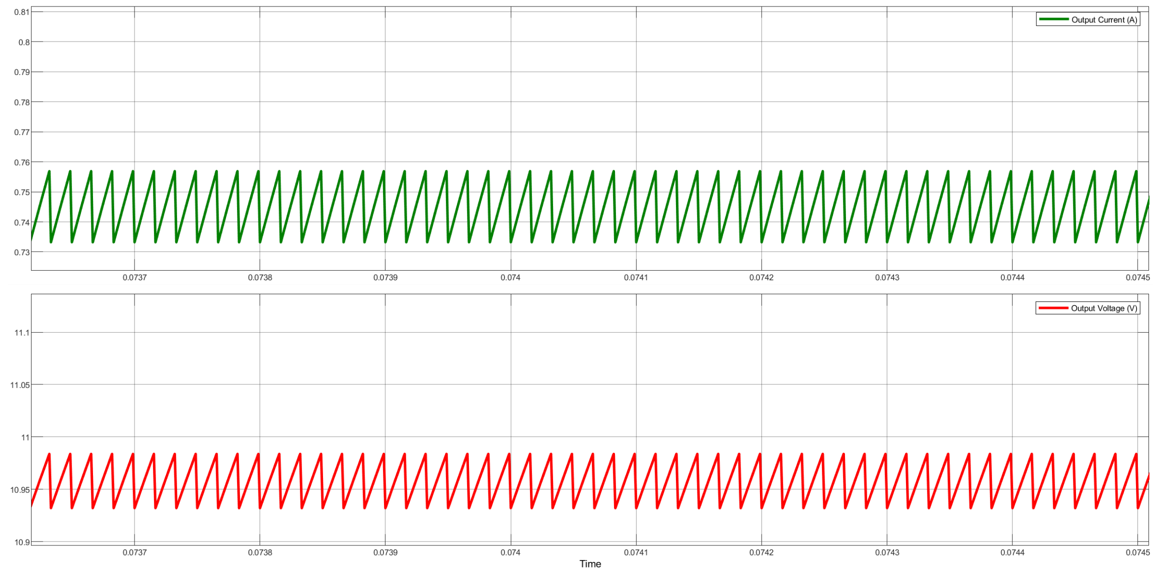

Figure 24: Output Voltage at full load and Output current at full load

- **At 75% Of Full load:** The input voltage is 12 V and the input current reduces to 0.4963 A. The reference current is set to 75% of full load current i.e. 0.5625 A. Following the linear model of LED, the output voltage is thereby 10.56 V. Thus, the duty cycle, D should be 88%. The duty cycle is adjusted to 89% to get the output current as 0.5548 A and the output voltage as 10.54 V. The output power is 5.85 W. The calculated values at this condition are:

  Efficiency: 98.18%

  Percent Flicker: 2.88%

  The output voltage and output current at 75% full load is depicted in the [Figure 25].

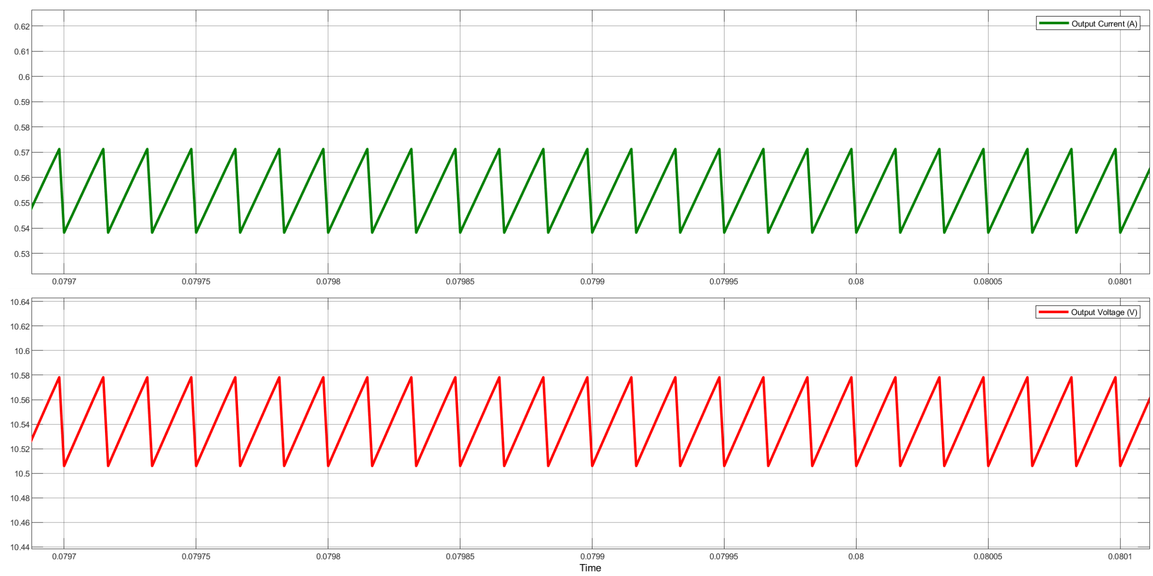

Figure 25: Output Voltage at 75% of full load and Output current at 75% of full load

- **At 50% Of Full load:** The input voltage is 12 V but the input current reduces to 0.3096 A. The reference current is set to 50% of full load current i.e. 0.375 A. Following the linear model of LED, the output voltage is thereby 10.14 V. Thus, the duty cycle, D should be 84.5%. The duty cycle is adjusted to 85.5% to get the output current as 0.3583 A and the output voltage as 10.11 V. The output power is 3.6 W. The calculated values at this condition are:

  Efficiency: 97.5%

  Percent Flicker: 5.7%

  The output voltage and output current at 50% full load is depicted in the [Figure 26].

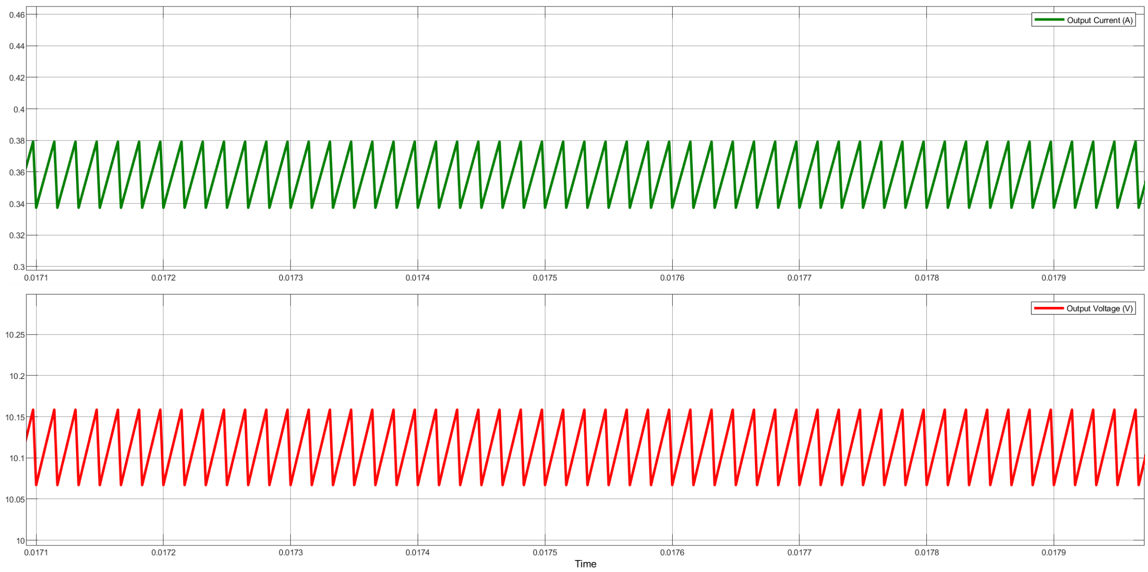

Figure 26: Output Voltage at 50% of full load and Output current at 50% of full load

- **At 25% Of Full load:** The input voltage is 12 V but the input current reduces to 0.1553 A. The reference current is set to 25% of full load current i.e. 0.1875 A. Following the linear model of LED, the output voltage is thereby 9.74 V. Thus, the duty cycle, D should be 82%. The duty cycle is adjusted to 82.4% to get the output current as 0.1838 A and the output voltage as 9.732 V. The output power is 1.79 W. The calculated values at this condition are:

  Efficiency: 95.98%

  Percent Flicker: 13.66%

  The output voltage and output current at 25% full load is depicted in the [Figure 27].

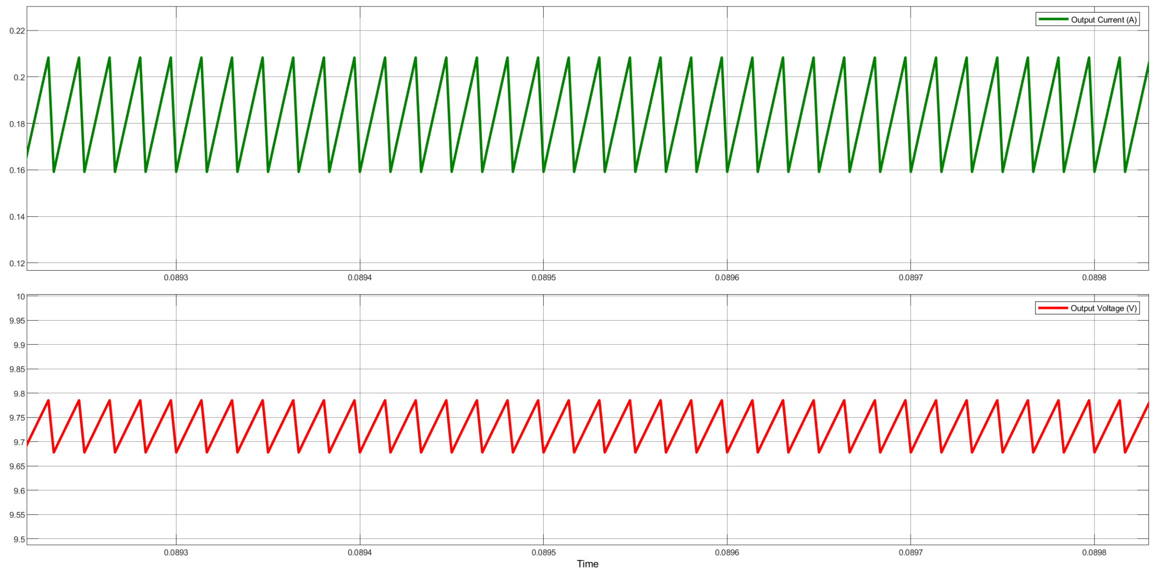

Figure 27: Output Voltage at 25% of full load and Output current at 25% of full load

4.2 Buck-Boost Driver

Buck-Boost driver is simulated using MATLAB Simulink at different load conditions for the same 8.23 W LED load. The values of various parameters are evaluated at different load conditions.Considering here [Figure 28].

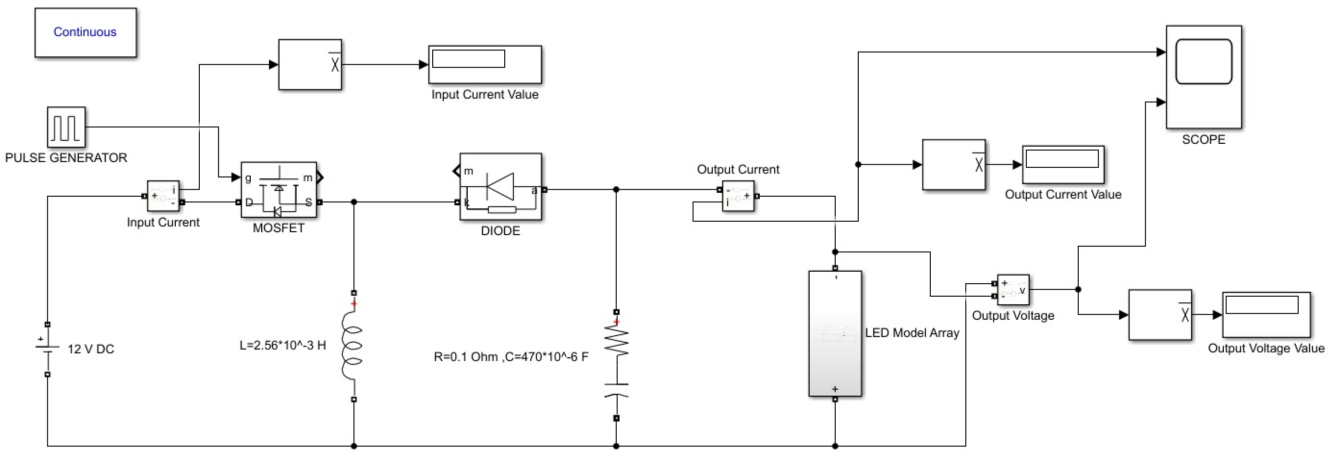

Figure 28: Simulated model of the Buck-Boost LED driver

- **At Full load:** The input voltage is 12 V and the input current is 0.7743 A. The reference current is set as full load current i.e., 0.75 A. Following the linear model of LED, the output voltage is thereby 10.97 V. Thus, the duty cycle, D should be 48%. The duty cycle is adjusted to 50% to get the output current as 0.7506 A and the output voltage as 10.97 V. The output power is 8.23 W. The calculated values at this condition are:

  Efficiency: 88.6%

  Percent Flicker: 4.7%

  The output voltage and output current at full load is depicted in the [Figure 29].

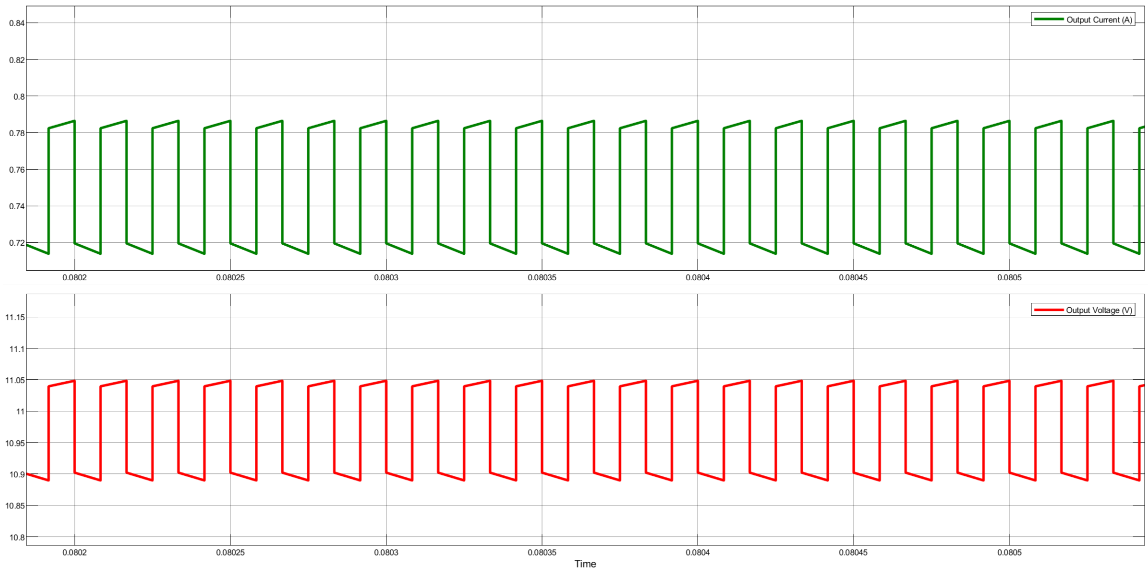

Figure 29: Output Voltage at full load and Output current at full load

- **At 75% Of Full load:** The input voltage is 12 V but the input current reduces to 0.5655 A. The reference current is set to 75% of full load current i.e. 0.5625 A. Following the linear model of LED, the output voltage is thereby 10.56 V. Thus, the duty cycle, D should be 47%. The duty cycle is adjusted to 49% to get the output current as 0.5646 A and the output voltage as 10.56 V. The output power is 6 W. The calculated values at this condition are:

  Efficiency: 87.9%

  Percent Flicker: 5.35%

  The output voltage and output current at 75% full load is depicted in the [Figure 30].

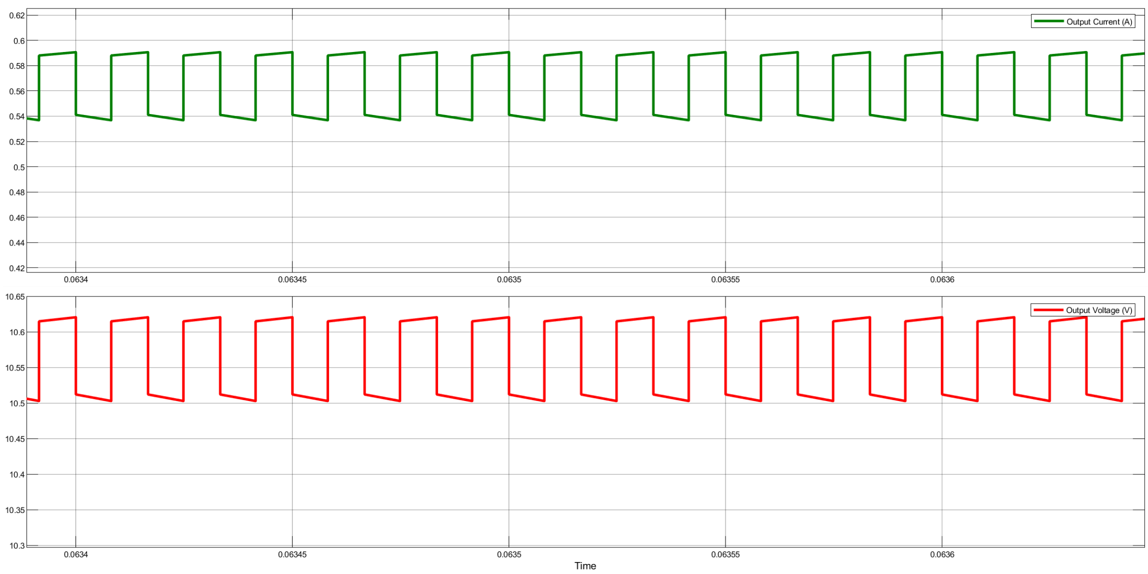

Figure 30: Output Voltage at 75% of full load and Output current at 75% of full load

- **At 50% Of Full load:** The input voltage is 12 V but the input current reduces to 0.3584 A. The reference current is set to 50% of full load current i.e. 0.375 A. Following the linear model of LED, the output voltage is thereby 10.14 V. Thus, the duty cycle, D should be 46%. The duty cycle is adjusted to 47.9% to get the output current as 0.3658 A and the output voltage as 10.13 V. The output power is 3.7 W. The calculated values at this condition are:

  Efficiency: 86.2%

  Percent Flicker: 4.11%

  The output voltage and output current at 50% full load is depicted in the [Figure 31].

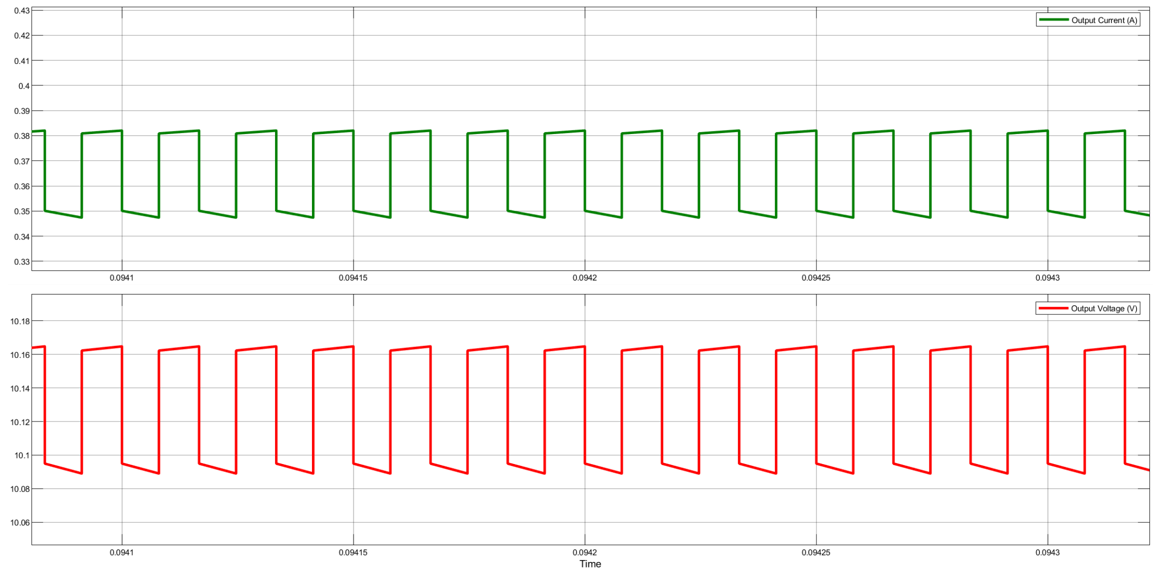

Figure 31: Output Voltage at 50% of full load and Output current at 50% of full load

- **At 25% Of Full load:**The input voltage is 12 V but the input current reduces to 0.189 A. The reference current is set to 25% of full load current i.e. 0.1875 A. Following the linear model of LED, the output voltage is thereby 9.74 V. Thus, the duty cycle, D should be 45%. The duty cycle is adjusted to 46.9% to get the output current as 0.1898 A and the output voltage as 9.745 V. The output power is 1.85 W. The calculated values at this condition are:

  Efficiency: 81.6%

  Percent Flicker: 5.03%

  The output voltage and output current at 25% full load is depicted in the [Figure 32].

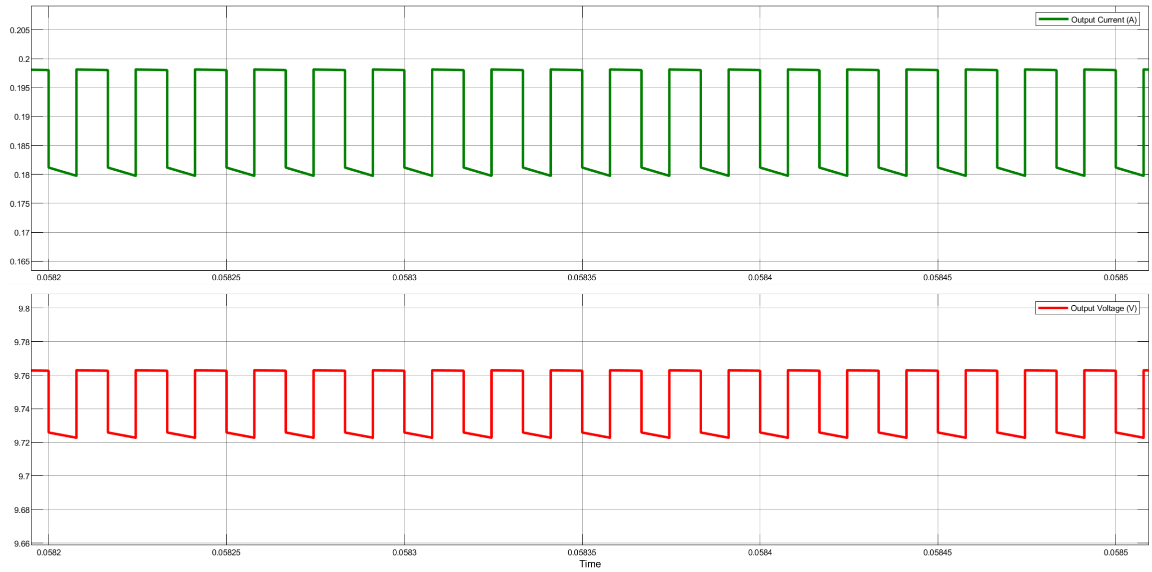

Figure 32: Output Voltage at 25% of full load and Output current at 25% of full load

4.3 Comparison of Figure of Merits

The two topologies have been simulated at the same load conditions. The two topologies have been compared on the following parameters:

4.3.1 Efficiency

Efficiency is one of the most important parameters for comparison. Since, the demand is rising for energy efficient technology, to replace an existing one the replacement should perform better than the present technology it is trying to replace.

Table 4: Efficiency Comparison at Different Loads

Load(%)	Buck Driver	Buck-Boost Driver
100	98.58%	88.6%
75	98.18%	87.9%
50	97.5%	86.2%
25	95.98%	81.6%

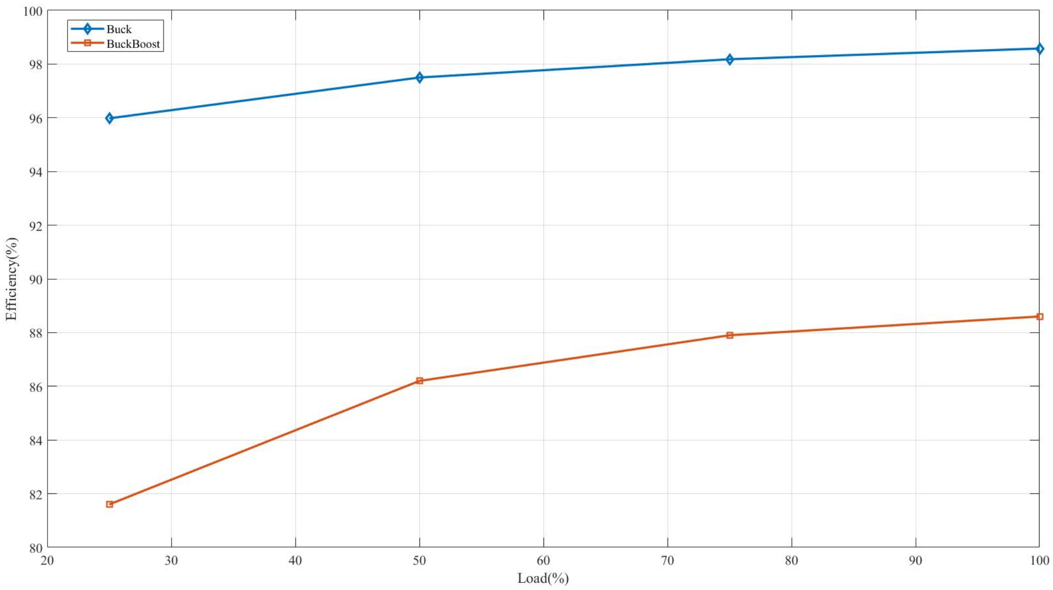

Figure 33: Comparison of Efficiency at Different Loads

In [Table 4], the efficiency of the buck driver ranges from a maximum value of 98.58 % at full load to a minimum of 95.98 % at 25 % of full load conditions. However, the efficiency of buck-boost driver reduces. It reaches a maximum of 88.6 % at full load and a minimum of 81.6 % at 25 % of full load. This is because of losses in the buck-boost converter due to leakage as well as more losses in passive components such as inductor and capacitors. All of these reduce the efficiency of the buck-boost driver when compared to the buck driver. In this parameter, the buck driver performs better than the buck-boost driver. The [Figure 33] depicts the comparison of efficiency at different loads.

4.3.2 Percent Flicker

The next parameter is percent flicker. Higher values of flicker can cause headaches, eye strain, and general eye discomfort. The lower the value, the better the lighting system.

Table 5: Percent Flicker Comparison at Different Loads

Load(%)	Buck Driver	Buck-Boost Driver
100	1.54%	4.70%
75	2.88%	5.35%
50	5.7%	4.11%
25	13.66%	5.03%

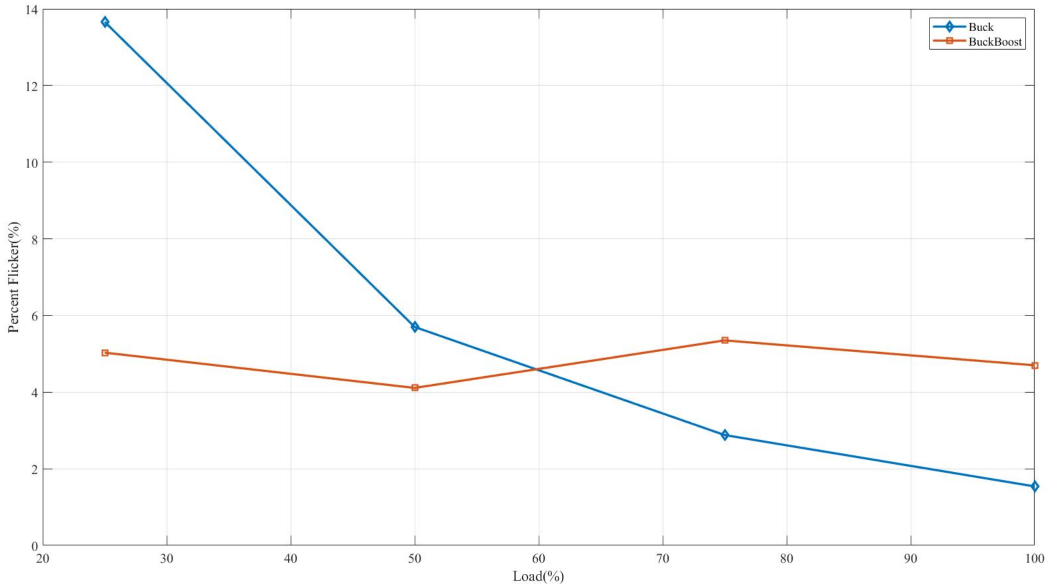

Figure 34: Comparison of Percent Flicker at Different Loads

The percent flicker is lower in the buck-boost driver when compared with buck driver as seen in [Table 5]. In buck-boost driver it is around 4.7 % to 5.03 % whereas in buck-boost driver it is ranging from 1.54 % to 13.66 %. In this parameter, buck-boost driver outperforms the buck driver.The [Figure 34] depicts the comparison of percent flicker at different loads.

4.4 Cost Analysis

The drivers are made up of components such as MOSFET, diode, inductors, capacitors, rectifiers, etc. All these components function together to produce the desired output.In both the topologies the fundamental components required are the same with one major distinctions.The value of the inductor in buck-boost is larger in size compared to buck driver. So, the cost of the inductor increases in case of buck-boost driver. So, the cost of the buck-boost driver increases.

Table 6: Buck Driver Component Costing (According to mouser.in)

Component Name(with rating)	Cost(in Rs)
300 μH(Rated Current = 1 A) Inductor	124.54
470 μF(Rated Voltage = 16 V) Capacitor	43.96

Table 7: Buck-Boost Driver Component Costing (According to mouser.in)

Component Name(with rating)	Cost(in Rs)
2.56 mH(Rated Current = 1 A) Inductor	231.99
470 μF(Rated Voltage = 16 V) Capacitor	43.96

So, the buck driver is a cheaper alternative here.

5 Chapter Five

Conclusion and Future Scope

This chapter deals with the conclusion based on the observations of the simulations. It also suggests the future scope of work on this thesis.

5.1 Conclusion

A buck and boost DC to DC converter can be used for the purpose of increasing the output voltage according to the variation in the duty cycle and the input voltage. In this operation, buck boost converter provides step down output voltage and the total circuit has drawn by using the same element of conventional DC-DC buck converter.
We observe that the efficiency of the buck driver ranges from a maximum value of 98.58 % at full load to a minimum of 95.98 % at 25 % of full load conditions. However, the efficiency of buck-boost driver reduces with decrease in load. It reaches a maximum of 88.6 % at full load and a minimum of 81.6 % at 25 % of full load. This is because of losses in the buck-boost converter due to leakage as well as more losses in passive components such as inductor and capacitors. All of these reduce the efficiency of the buck-boost driver when compared to the buck Driver. In this parameter, the buck driver performs better than the buck-boost driver. The percent flicker is lower in the buck-boost driver when compared with buck driver. In buck-boost driver it is around 4.7 % to 5.03 % whereas in buck-boost driver it is ranging from 1.54 % to 13.66 %. In this parameter,buck-boost driver outperforms the buck driver.
However the cost of the buck-boost driver increases here due to the large size of the inductor. So the buck driver is more cost effective in this case.

5.2 Future Scope

In the earlier works, models of LED modules made of identical LEDs arranged in series–parallel combinations have been reported. In the present times, it has become a practice to use more than one color of LED in a single module especially for tuning and blending of source color.The basic model of a single constituent LED chip is necessary for formulating the model of the whole module. Though in this study we have considered only the linear model of LED but there are four basic LED models available as the alternatives, namely, parabolic, exponential, and modified Shockley models. An experimental comparison can be carried out among these four to identify the suitable LED model in terms of accuracy in the linear and non linear electrical operating regions.Also, the configuration of both the topologies can be improved by designing it in closed loop structure and implementing a proper controller circuit.

References

[1] Yijie Wang, Yueshi Guan, Jiaoping Huang, Wei Wang, and Dianguo Xu. A single-stage led driver based on interleaved buck–boost circuit and llc resonant converter. *IEEE Journal of Emerging and Selected Topics in Power Electronics*, 3(3):732–741, 2015.

[2] Renbo Xu, Yongzhi Li, Lixin Zhong, and Jiaming Liu. Research of an efficient led lighting driver based on boost-buck converter. *Circuits and Systems*, 2014, 2014.

[3] Understanding led drivers. https://www.1000bulbs.com/pdf/understanding-led-drivers.pdf, May 2014.

[4] R Abhishek, Pallavi Zoting, and Purva Ragit. Design and analysis of a dc-dc buck converter and boost converter to achieve high efficiency by altering duty cycle and input voltage. *International Journal of Scientific and Research Publications*, 10(6):731–738, 2020.

[5] Yuanmao Ye, Ka Wai Eric Cheng, Junfeng Liu, and Cuidong Xu. Bidirectional tapped-inductor-based buck-boost convertor and its circuit application. In *2013 5th International Conference on Power Electronics Systems and Applications (PESA)*, pages 1–7. IEEE, 2013.

[6] Led working principle. https://studiousguy.com/led-working-principle/.

[7] Muhammed. H Rashid. *Rashid Power Electronics Handbook*.

[8] Tore M. Undeland Ned Mohan and William P.Robbins. *Power Electronics Handbook*.

[9] Farhan Sheikh. Led driver circuit working and applications. https://eeeproject.com/led-driver-circuit/, September 2017.

[10] Vishwanath Gupta, Biswarup Basak, Kamalika Ghosh, and Biswanath Roy. Universal control algorithm for automatic current regulated led driver. *International Journal of Power Electronics*, 12(2):169–190, 2020.

[11] Led driver basics and its circuit design. https://www.apogeeweb.net/article/78.html, April 2018.

[12] Bhim Singh and Ashish Shrivastava. Buck converter-based power supply design for low power light emitting diode lamp lighting. *IET Power Electronics*, 7(4):946–956, 2014.

[13] Mousumi Biswal. *Control techniques for DC-DC buck converter with improved performance*. PhD thesis, 2011.

[14] Jitendra Bakliwal and Mruttanjaya Aspalli. Buck converter based led driving topology for solid state luminaire. *International Journal of Computer Science Trends and Technology (IJCST)*, 9(4), 2021.

[15] M Gupta and SP Phulambrikar. Design and analysis of buck converter. *International Journal of Engineering Research & Technology*, 3(3):2346–2350, 2014.

[16] J Marcos Alonso, Antonio J Calleja, David Gacio, Jesús Cardesín, and Emilio López. A long-life high-power-factor hps-lamp led retrofit converter based on the integrated buck-boost buck topology. In *IECON 2011-37th Annual Conference of the IEEE Industrial Electronics Society*, pages 2860–2865. IEEE, 2011.

[17] Renbo Xu, Shaoyi Li, and Zhilin Ding. A research on high-power led lighting drive based on buck-boost converter. In *8th International Conference on Management and Computer Science (ICMCS 2018)*, pages 479–483. Atlantis Press, 2018.

[18] Dr. P.S Bhimbra. *Power Electronics handbook*.

[19] Biswadeep Gupta Bakshi and Biswanath Roy. Electrical model formulation for multicolor light-emitting diode modules and its application to design dimmable driver. *International Journal of Circuit Theory and Applications*, 49(6):1559–1582, 2021.

[20] Subhrajyoti Guha Satarupa Roy, Chandrani Pal. Buck converter based led driver. In *IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE)*, volume 17. IOSR-JEEE, 2022.

[21] R Gunabalan, DR Binu Ben Jose, and Padmanaban Sanjeevikumar. Buck–boost led driver with dimming characteristics. *Advances in Power Systems and Energy Management: ETAEERE-2016*, pages 295–305, 2018.