Studies on Lighting Deisgn for Temple Architecture

A thesis submitted towards partial fulfillment of the requirements for the degree of

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in
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Submitted by,
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CERTIFICATE OF RECOMMENDATION

This is to certify that the thesis entitled **"Studies on Lighting Design for Temple Architecture"** is a bonafide work carried out by **ANINDYA KUMAR DAS**, under my supervision and guidance for partial fulfillment of the requirement of **M. Tech. (Illumination Technology and Design)** in School of Illumination Science, Engineering and Design, during the academic session 2018-2021.

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DECLARATION OF ORIGINALITY AND COMPLIANCE OF ACADEMIC ETHICS

I hereby declare that this thesis contains a literature survey and original research work by the undersigned candidate, as part of my **M. Tech. (Illumination Technology and Design)** studies during the academic session 2018-2021.

All information in this document has been obtained and presented by academic rules and ethical conduct.

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Acknowledgment

For preparing this report many resources have been studied. Apart from the effort, the success of this project depends largely on the encouragement and guidelines of many others. I would like to show my greatest appreciation to Dr. Biswanath Roy sir and Dr. Pradip Kr Maiti sir. I feel motivated and encouraged every time I attend their meeting. They gave me valuable suggestions and made a lot of contributions to this project.

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Signature

Date:

This thesis is dedicated to my loving parents

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Abstract

Illumination plays a critical role in architectural lighting. Adequate illumination is crucial to bring out different looks of a building through different effects or positioning of the fixtures. Architecture is an art that works hand-in-hand with science to design places where people can observe the beauty of any building & illumination is a part to bring out that beauty. Nowadays designers & architects are showing more inclination towards the effect of lighting because now they can use modern LED lighting with advanced technology for improvement. It can be a single color design or in multicolor design, depending upon the requirements & site conditions given to the designers they can provide a suitable design to their client. This thesis represents the design and implementation of light sources or fixtures for a more efficient way of using lighting control technology with different effects by changing the CCT & beam angle of the fixtures.

The lighting design and simulation work in the subsequent chapters are performed in Leksa Lighting Technologies Pvt. Ltd., Mangalore branch during the working period of the author of the thesis.

Literature Review

To see or observe things lighting is a critical concept for humans to function. Lighting can affect humans psychologically & physiologically which means influencing their emotions. Lighting must be done in such a way that it's eye-pleasing with proper planning, positioning of the luminaries & mostly management of the energy. For commercial area or indoor area applications, it's very much important to maintain illimitation level & uniformity level up to the standards [1]. For outdoor lighting main critical thing is to control the light pollution. Conversely, illumination in excess of the required amount does waste energy and needlessly increases the cost of a lighting system. The increase in the electricity demands day by day due to the entry of new upcoming electronic devices into human life, there is a gap between supply and demand which is increasing rapidly. The lighting of our life generally consumes 20-50 % of the total electricity consumption [2]. For reducing wastage of energy everything is controlled & monitored. Nowadays it's called smart lighting control technology. With this technology, we can track our lighting system with a single touch. Smart lighting control systems have enabled energy conservation and increased energy efficiency everywhere such as indoor buildings, outdoor façade lighting, and industrial areas. The most popular lighting control techniques are DALI, DMX, or other remote base controlling which have excellent dimming control techniques [3]. By using these dimming control, the lifespan of LEDs are becoming huge. "Green Lighting" or "Energy Efficient Lighting" is listed as one of the solutions to save energy. By energy-efficient lighting systems we mean the use of LEDs, lamps with high efficacy, use of daylight, use of sensors & long-life lamps. India is shifting towards energy-efficient lighting as it can improve the efficiencies of energy utilization and is not harmful to human health and does not impairs the environment. Energy efficient lighting means obtaining adequate lighting and consuming less electricity and should be free from polluting the environment.

In this thesis proposed light control scheme is a simulated representation. For the simulation purpose of this project, 3DS Max software is used.

Research Statement

To design a lighting system to illuminate an architectural building and at the same time implement control through a lighting control scheme.

Objectives

The main objectives of this project are-

- To design a lighting design for the temple.
- To design proper energy management.
- To implement controlling technique.

Chapter: 1
Background Theory

1. Background Theory

1. LED (Light Emitting Diode)

LED (light emitting diode) is a semiconductor device. When an electric current passes through the LED, it starts the emit light. When the particles (electrons and holes) combine within the semiconductor material then the light is produced. As the light is generated in a semiconductor material, LEDs are known as solid state devices. The particles are contained within the energy bands inside the semiconductor material of the LED. The bandgap determines the photon energy which determines the wavelength of the emitted light and it's color. Different semiconductor materials with different bandgaps produce different colors of light. The color of a LED can be tuned by altering the composition [5] [6].

But as we know, for any product there are always some advantages and disadvantages.

Advantages of LEDs:

- Very low voltage and current are enough to drive the LED.
- Voltage range can be low as 1 to 2 volts and Current range 5 to 20 milliamperes.
- Total power output will be less than 150 milliwatts.
- The response time is very less – only about 10 nanoseconds.
- The device does not need any heating and warm-up time, which is an advantage over gas discharge lamps. Thus turn on and off can be done quickly.
- Miniature in size and hence lightweight.
- Has a rugged construction and hence can withstand shock and vibrations.
- An LED has a lifespan of more than 10 years, depending upon the uses it can vary up to 15 - 20 years.
- Various colors are available.

Disadvantages of LEDs:

- A slight excess of voltage or current can damage the device.
- The device is known to have a much wider bandwidth compared to the laser.
- Efficacy is lower compared to the other light source available.
- The temperature depends on the radiant output power and wavelength.
- For LED required more power to operate compared to the normal diodes available.

1.1. Construction and Working Principle

LEDs are a p-n junction diode. When the light emits in a forward condition then it is called a light emitting diode. The LED includes two terminals an anode and a cathode. The LED is designed through the deposition of three semiconductor layers those are p-type region, active region, and n-type region. The P-type region consists of the holes, the n-type region consists of the electrons whereas in the active region both holes and electrons are present. These three layers are arranged one after another, the top region is known as the p-type region, the middle part is known as the active region, and the lower part is known as the n-type region [5] [6].

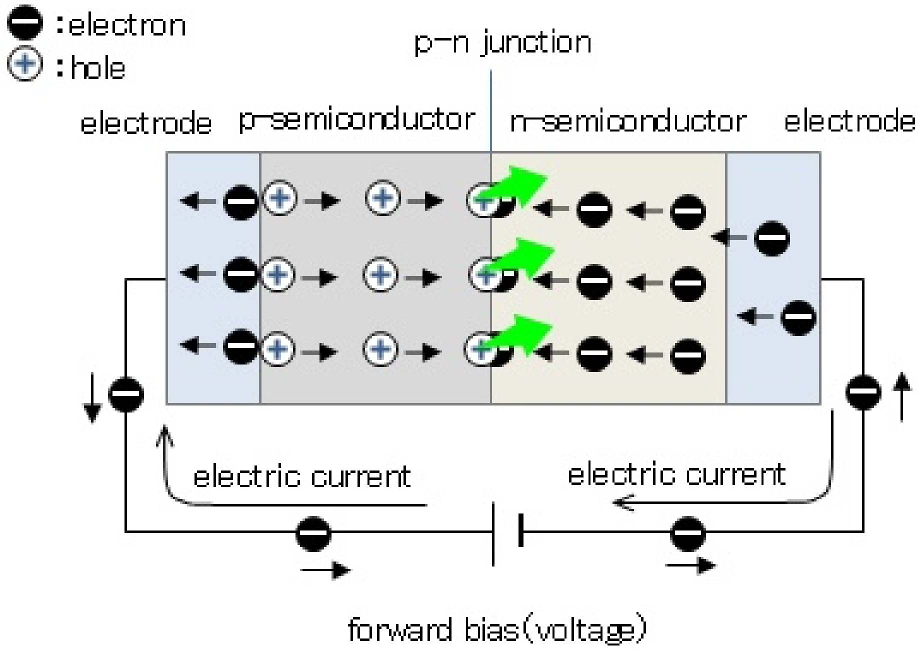


Figure 1: LED in forward biased condition

When no voltage supply is applied to the LED, these regions remain stable which means no flow in between electrons and holes. But once the voltage is applied to the LED, it goes in forward biased condition, thus the regions became unstable means holes from the p-region and electrons from the n-region move to the active region. The active region is also known as the depletion region. In forward biased condition electrons and holes are moving fast across the junction and they are constantly combined and canceling each other out. Soon after the electrons are moving from the n-type region the to p-type region. At this time, an electron transits from a higher energy state to a lower state. Hence it gives them a little burst of energy which is equal to the energy gap between these two energy levels, this energy takes the form of light.

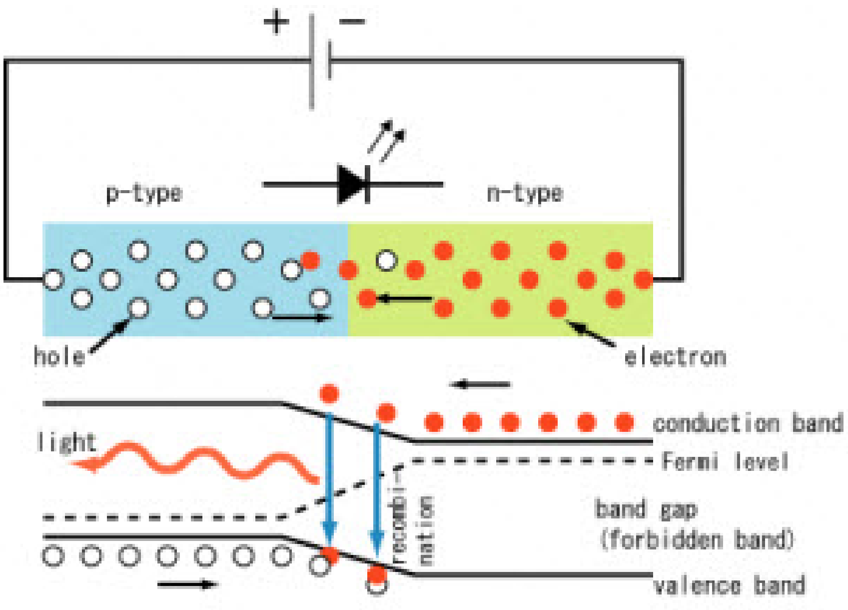


Figure 2: Principle of LED emission

Figure 3 explains different emission wavelengths are different among semiconductor materials. For manufacturing LED there are main semiconductor materials are -

- Aluminum gallium indium phosphide (AlGaInP): Yellow, orange, and red high-brightness LEDs.
- Indium gallium nitride (InGaN): Blue, green, and ultraviolet high-brightness LEDs.
- Aluminum gallium arsenide (AlGaAs): Red and infrared LEDs.
- Gallium phosphide (GaP): Yellow and green LEDs.

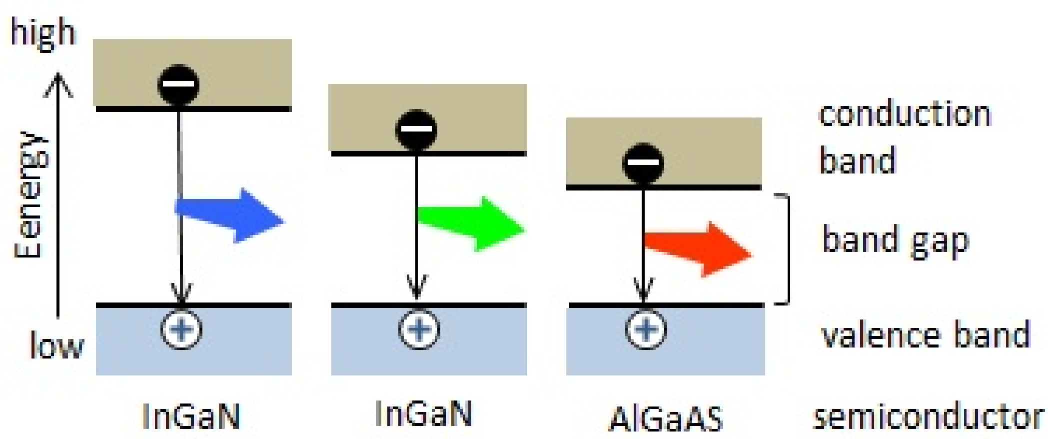


Figure 3: The difference in the emission color by the semiconductor material

1.1.1. Electrical Characteristics of LED

LEDs are low voltage devices. Single indicator LEDs require 2 to 3 volts of direct current, with the current in the range from 1 to 100 mill amperes (mA). An illumination-grade LED containing a single semiconducting element requires the same voltage, but operating currents are much higher, typically several hundred mill amperes (mA). A device containing multiple elements connected in series will require a higher voltage corresponding to the larger number of individual elements in the device.

Forward Current of LED

The amount of current flowing through in normal operating conditions is very important because, the brightness of the light depends on it. LEDs are normally rated with the maximum forward current that is safe to pass through it without any heating and burning effect of it.

Forward Voltage of LED

Light Emitting Diodes are rated with the forward voltage which is the amount of forward voltage required to conduct the LED electrically. As an example, all 5mm LEDs are normally rated with a forward current of 20mA, but the forward voltage varies depending on the color of light generation. Normally, red-colored LEDs are rated at 2.2V, blue LEDs are having a maximum voltage rating of 3.4V and the maximum voltage rating of white LEDs are in the order of 3.6V.

Polarity

LEDs require a specific electrical polarity. Applying voltage in reverse polarity can destroy them. Manufacturers provide specifications about the maximum reverse voltages acceptable for LED devices; 5 volts is a typical maximum rating.

V-I Characteristics of an LED

V-I characteristics or a current-voltage characteristic, also known as a curve (current-voltage curve). It is a relationship between the electric current flowing through a circuit, apparatus, or substance and the associated voltage. It is often represented in a chart or graph, where voltage(v) is measured along the x-axis and current(I) is measured along the y-axis.
The V-I graph provides useful information regarding resistance and deconstructs an electronic component. It also reveals a device's functioning area.

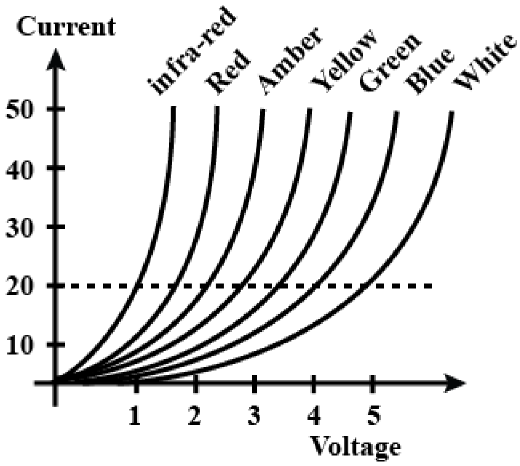


Figure 4: V-I Characteristics Graph

1.2. Types of LED Chips

- Dual In-Line Package
- Chip on Board
- Surface Mounted Diode

1.2.1. Dual In-Line Package (DIP)

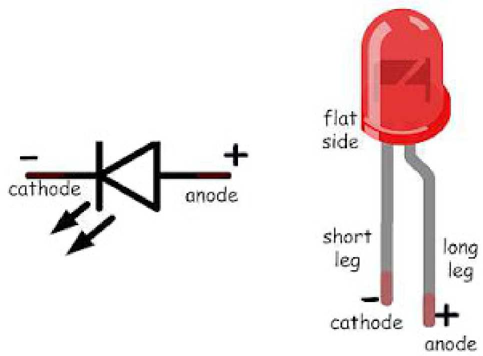


Figure 5: Construction of LED

DIP (Dual In-Line Package) LEDs are the traditional LED lights. It is what most people think of when they picture LED lights. They look the most like a traditional light with the chip encased in hard plastic generally used with two straight parallel connecting pins.

1.2.2. Chip on Board (COB)

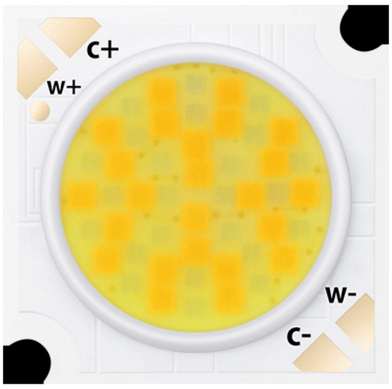


Figure 6: COB LED Chip

Chip on Board (COB) is the most recent development in LED technology. It uses multiple diode chips typically around 9 or more. There is no casing with COB technology which enables a much denser LED array of light compared to SMD. COB chips are being used in an array of different devices. The great advantage of COB modules lies in the highly homogeneous light they emit. That means a consistent light beam is given off, without any visible individual light points. By then adding a ceramic substrate, the best conditions are created for optimal cooling, which in turn serves to increase efficiency and lengthen service life. Typically, in small devices such as cameras and smartphones, this is due to a high amount of lumens created for a very small amount of energy. Figure 6 shows a COB chip.

1.2.3. Surface Mounted Diode (SMD)

Figure 7: SMD LED Chip

Surface-mounted diode (SMD) LED chips are much smaller and more efficient LEDs than the previous DIP chips. They have become popular due to their versatility and are typically mounted and soldered onto a circuit board. SMD chips have become very important for the development of the LED industry as three diodes can be put on the same chip. As well as the brightness being significantly better, they can change color. Some of the chips are made small to be used in high-end electronics such as laptop computer indicator lights. They are also standalone chips that predominantly used LED strips or LED recessed downlights or any outdoor application.

There are some significant differences in between COB LED Chips & SMD LED Chips. Such as -

- Compared to SMD, COB LED chips are small in size. But the temperature gets as high as 70+ degrees which requires a bigger & better heat sink. In the case of SMD large LED spacing on the board helps heat to dissipate faster.
- SMD chips have higher luminous efficiency than COBs.
- With good performance of heat dissipation, SMD chips could pass the LM80/TM21 tests. While few COB chips could pass that.

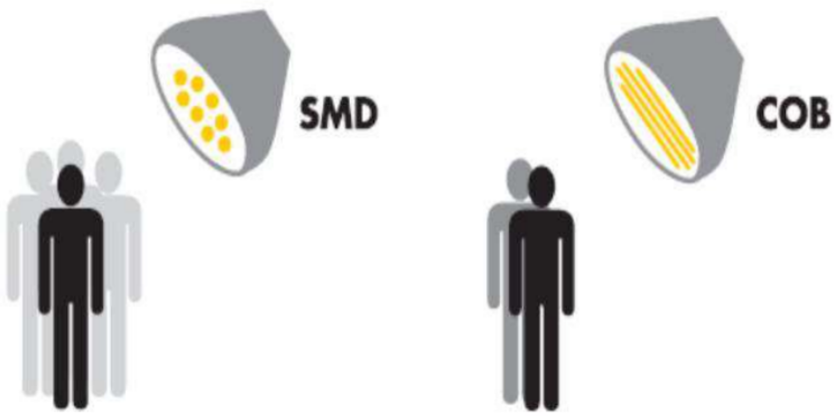


Figure 8: Light Output comparison of SMD LED and COB LED

As SMD LEDs are singular light sources, they can produce multiple directional shadows whereas in COB LED Chips many light sources are combined so that they can cancel out the multiple shadows created by the light fixture. Figure 8 shows the light output comparison of SMD and COB LED fixtures. In both SMD & COB type LEDs, various CCTs are available. For Single color temperature, the CCT is available from 1800K to 7000K. Other than that we have High Power LEDs, Bi-Color LED, RGB, RGBA, and RGBW LEDs in various LED packages. Some of the LEDs are used for agricultural purposes.

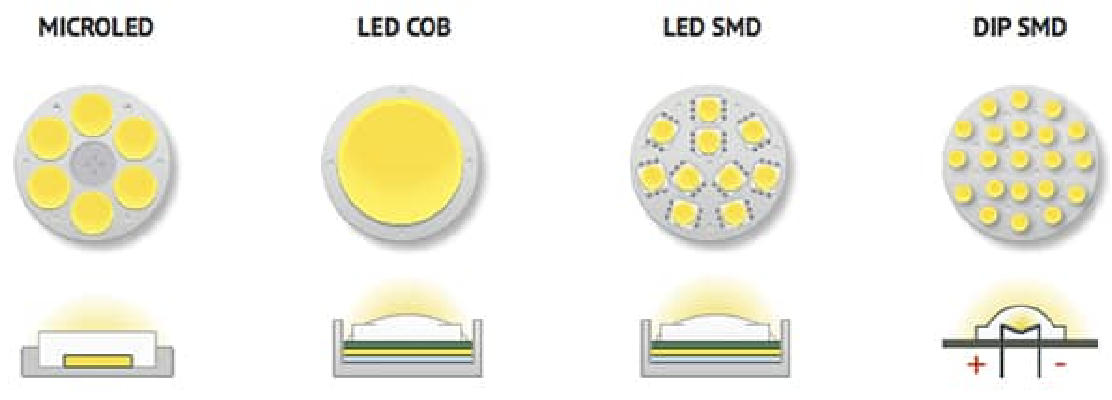


Figure 9: Different SMD & COB LED Chip

1.2.4. Bi-Color LED Chip

It consists of two LEDs in a single case. The wiring is parallel, i.e one is in the forward direction and the other one is backward. The color variation is done by an alternative flow of current between the two dies. Figure 9 shows the Bi-colour LED.

Figure 10: Bi-Color SMD LED and COB LED

1.2.5. High power LED Chip

Used primarily for outdoor and industrial lighting, high-power LEDs are all about efficiency and lowering forward voltage (Vf) to achieve a higher lumen/watt. High-power LEDs are the flagship of the industry and lead the pack in efficiency, helping customers keep their material costs in check and giving manufacturers a broad selection of high-performance LEDs.

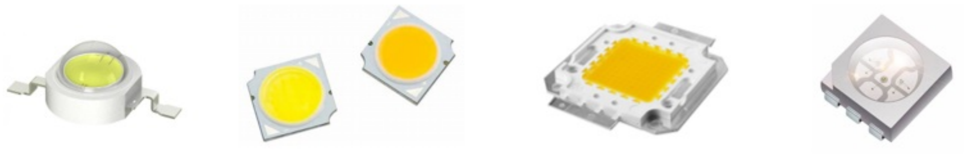


Figure 11: High Power LEDs in various LED Package

1.2.6. RGB & RGBW LED Chip

RGB emits red, green, and blue light & also recombines it to produce multiple colors. By combining these three colors we can achieve pure white color. In RGBW LEDs it has red, green, blue & white colors. It has four LEDs in a single chip. By adding white color to LED the color variation becomes more. It has much more application nowadays.

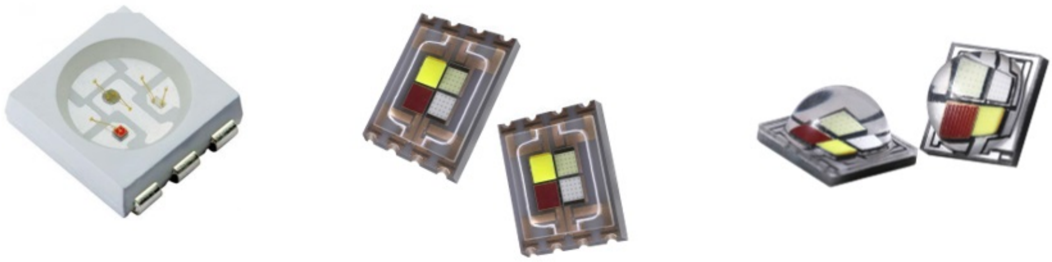


Figure 12: RGB & RGBW LEDs in various LED Package

1.3. LM80 Test Report

LM-80 Test Report describes lumen depreciation of LED Chip. The North American IES standard LM80 determines a test method by which a batch of LEDs is tested at a specified drive current and ambient temperature. At intervals during the test luminous flux, and CCT are measured. At least 2 ambient temperatures are used in the test: 55°C, and 85°C. The LEDs are operated at these temperatures and a specific drive current for a period of 1000hrs, then the LEDs are taken from the oven, allowed to cool to 25°C ambient, and their light output characteristics are measured. The LEDs are then placed back in the oven and the process is repeated for a minimum of 6000hrs (approximately nine months). Once the

LM80 test has concluded, the measurements are used to determine a depreciation curve for the luminous flux at each temperature. The data is extrapolated using the method described in the North American Technical Memorandum TM21 to determine the ”Lumen Maintenance Life Projection (Lp)”. The endpoint of the extrapolation is typically 70% of the initial light output. LM-80 refers to a method for measuring the lumen depreciation of solid-state light sources, such as LED packages, modules, and arrays.

1.4. TM21 Test Report

It is the Illuminating Engineering Society of North America (IESNA) approved method for measuring Lumen Maintenance of LED Light Sources. This document provides recommendations for projecting long-term lumen maintenance of LED light sources using data obtained when testing them per IES LM80. The results can then be used to interpolate the lifetime of an LED source within a system (luminaries or integrated lamp) using such a thing as testing, which is a mathematical method based on LM.
Among other things, TM-21-11 will consider:

- If the total LM-80 data period is between 6,000 and 10,000 hrs, we consider the last 5,000 hours.
- If the total data period is above 10,000 hours, we use the last half of the collected data.
- Projections are limited to 6 times the available LM reported lifetime may or not be the same.

The method will provide a projected lifetime for the LED source or system. Life notation results will then use the following standardized nomenclature: Lp (Yk) P: Lumen maintenance percentage. For LED luminaries we consider L70 to be the standard. After 30% lumen depreciation, we consider the system is not performing its duty anymore and should be replaced (see Lifetime section of Lighting Guide for more details) Y: Length of LM in thousands of hours Example: L70 (6k) = 36,000 hours

1.5. LED Driver

The driver circuit must provide sufficient current to light the LED at the required brightness, but must limit the current to prevent damaging the LED. The approximately constant over a wide range of operating current; therefore, a small increase in applied voltage greatly increases the current. Very simple circuits are used for low More complex, current source circuits are required when driving high to achieve correct current regulation. The 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, and the low voltage and high-frequency AC (such as the output of the electronic transformer). The output of LED driver power is mostly a constant current source that can change voltage with the change of LED forward voltage drop. So, LED is a constant current source. The internal circuit of a LED

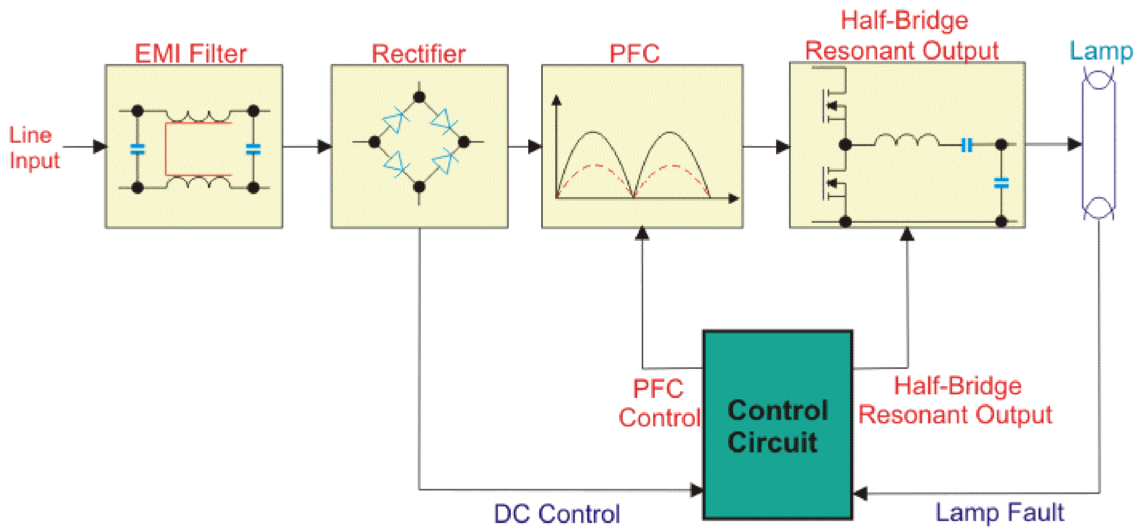


Figure 13: Simplified internal circuit of LED Driver

driver can be simplified in Figure 13 The circuit operates as follows:

LEDs require drivers for two purposes:
1. LEDs are designed to run on low voltage (12-24V), direct current electricity. However, most places supply higher voltage (120-277V), alternating current electricity. An LED driver rectifies higher voltage, alternating current to low voltage, and direct current.
2. LED drivers also protect LEDs from a 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.
In summary, LED drivers to convert higher voltage, alternating current to low voltage, and direct current. They also keep the voltage and current flowing through an LED circuit at its rated level.
In India, there is standard voltage supply is 240 V, 50 Hz AC. But the driver is made so that it can operate on various voltage ranges.
The basic components used in the drivers are listed below:

- EMI filter: Blocks any electromagnetic Interference.
- Rectifier: Converts AC power to DC power.
- PFC: It stands for Power Factor Correction.
- Half-Bridge Resonant Output: Converts DC to AC voltage with high frequency.
- Control Circuit: Controls voltage and current across and through the lamp respectively.

- A Surge Protector is connected. The Surge Protection Device electrical installation protection system.

1.5.1. Types of LED DC Driver

There are mainly two types of LED drivers, constant-current and constant-voltage. Each type of driver is designed to operate LEDs with a different set of electrical requirements. When replacing a driver, the old driver's input/output requirements must be matched as closely as possible. Key differences are detailed below -

1.5.1.1. Constant-Current LED DC 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, labeled in amps or milliamps, along with a range of voltages that will vary depending on the load (wattage) of the LED.
The output current of the constant current drive circuit is constant, but the output DC voltage varies in a certain range with the different sizes of the load. The load resistance is small, the output voltage is low, and the greater the load resistance is, the higher the output voltage is. The constant current circuit is not afraid of load short circuits, but it is strictly forbidden to load fully open. The designer should be paid attention to the maximum withstand current and voltage used, which limits the number of LEDs used.

1.5.1.2. Constant-Voltage LED DC 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 12V DC or 24V DC, or 36V DC voltage. When the parameters in the voltage stabilizing circuit are determined, the output voltage is fixed, whereas the output current varies with the increase or decrease of the load. The voltage stabilizing circuit is not afraid of load opening, but load short circuits are strictly forbidden. A regulated drive circuit powers the LED. Each string requires a proper resistor to average the brightness of each string LED. The rectified voltage changes will affect the brightness.
While planning any lighting design, we have to always consider the total load or load given to the DC driver. As we know the power factor is a very critical parameter when we are designing the lights and a key value that evaluates the pollution caused by the electrical device to the electricity grid. Normally it has to be over 0.9 according to the standards.

1.5.1.3. Power Factor

Power factor is an expression of energy efficiency. It is usually expressed as a percentage, & the lower the percentage, the less efficient power usage is.
Power factor (PF) is the ratio of working power, measured in kilowatts (kW), to apparent

power, measured in kilovolt amperes (kVA). Apparent power, also known as demand, is the measure of the amount of power used to run machinery and equipment during a certain period. It is found by multiplying (kVA = V x A). The result is expressed as kVA units.
Power Factor expresses the ratio of true power used in a circuit to the apparent power delivered to the circuit. A 96% power factor demonstrates more efficiency than a 75% power factor. Power Factor below 95% is considered inefficient in many regions. When the lighting engineers are designing the products, they check the PF vs. load value from the LED driver datasheet to make sure the PF is sufficient in working condition.

1.5.2. Dimming Control or Operation

Both constant-current and constant-voltage LEDs and drivers can be made with a dimming capability, though both LEDs and drivers must specify that they are dimmable on the product datasheet for that assertion to be made. If the specs don't mention dimming at all, it is safe to assume that the product is not dimmable. Dimmable external drivers often require an external dimmer, or other dimming control devices specified on the product datasheet (namely TRIAC, Trailing Edge, or 1-10v dimmers) to work. Since technologies are improving rapidly, it's best to test specific LED/dimmable driver combinations for acceptable dimming performance before making large purchases if brand-specific dimmer compatibility charts are not available.
Dimming LEDs varies with what kind of power you are using. Dimming is the process of controlling the amount of electrical power supplied to a light source or an LED. The four most popular methods for dimming LED lights are described below and cover 0-10Volt dimming, PWM(Pulse Width Modulation) dimming, Forward-Phase dimming(sometimes referred to as "Triac" or Incandescent Dimming), and Reverse-Phase dimming (sometimes referred to as an ELV or Electronic Low Voltage Dimming).

- **0-10V Dimming**
  This method can use several devices to control the dimming. This requires additional low voltage wiring but is more accurate than AC phase dimming. This is also known as DC Dimming. This gives a full range of 0-100% dimming.
  0-10V dimming applies a direct current voltage (DC) between 0 and 10 Volts to produce light at varying intensity levels. At 10V, the lights controlled by the dimmer are at 100% brightness. At 1V, the lights are at 10% measured brightness, which may be perceived as 32% brightness. At 0 Volts, it either turns the lights off or has the lights dimmed to the lowest possible level and a switch is required to turn the lights completely off.
  0-10V dimming started as a method for dimming fluorescents but is also used on LED lighting today. It's typically used in offices, retail spaces, and homes with fixtures that have an LED driver designed for 0-10VDC dimming input. While it can be used for RGB or RGBW color-changing lights, there are some limitations. Each of the three or four colors needs to be assigned a zone so that the controller can adjust the intensity of each color separately to produce a range of color possibilities. If the color-changing lights require additional inputs beyond intensity, a different dimming

method should be used. For applications like entertainment spaces, it's common for people to use DMX512 protocol products instead, allowing them to connect the lights to a computer or any smart device.

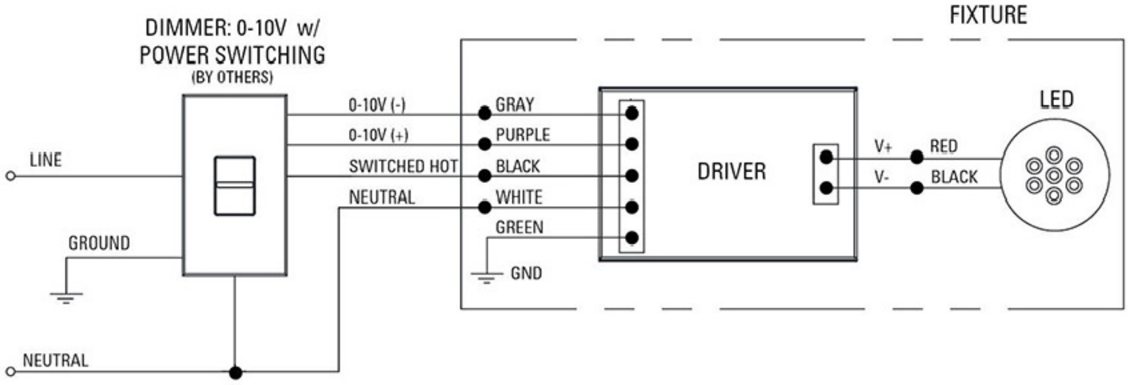


Figure 14: 0-10 V Dimming Circuit

- **Pulse Width Modulation (PWM Dimming)**
  PWM is a dimming method that is prevalent in LEDs that use constant-current drivers. This technique works by adjusting the duty cycle of the current, resulting in changes to the average current in the string. PWM is effective for accurate light dimming requirements, as it can handle high dimming ratios at 100 Hz (high frequency, so that the human eye cannot detect the flickering effect), with minimal effects on the LED color/color temperature. To achieve dimming, the LED is toggled at a very rapid rate. For instance, at the highest setting (full output), the LED stays"on" and is never toggled. At 75% dimming, the lights are only "on" 25% of the time. When plotted on a graph, shifts in current appear to be staggered, like a set of evenly spaced blocks or stairs without a long-term ascending or descending pattern (rates/values of dips/increases are constant).
  This type of dimming is ideal for lighting systems that need to be dimmed below 40% in a very consistent manner. PWM is suitable for color-mixing requirements, due to its precise dimming properties. Lastly, it can be incorporated into electronic systems via direct digital control.

The benefits of Dimming

A dimmer light switch provides adjustable voltage to a light fixture. This controls the brightness of a lighting fixture, allowing it to fade up brighter or down to dimmer lighting. Light dimming switches are very safe and efficient. No special wiring is needed to install a residential dimmer switch.

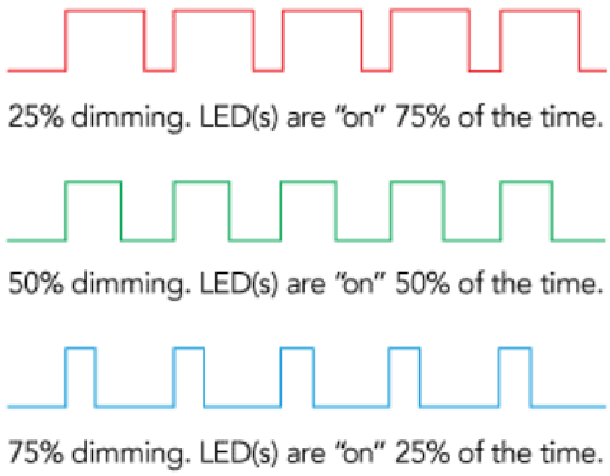


Figure 15: PWM Control Signal for dimming at 25%, 50% & 75%

To make the lighting dimming, you need to buy a dimmer and a dimming LED lighting (with a dimming LED driver). There are so many benefits of dimming lighting for your home or business place. The benefits of LED lighting can be further enhanced simply by dimming light to appropriate levels needed for the application if the amount of energy consumed is reduced while dimmed. The dimmed LED lamp also operates in a cooler condition, which can save air conditioning costs. Dimming then further increases the operating life of the LED lamp [7].
Daylight harvesting is the concept of using natural light to enhance indoor lighting, thereby, reducing the generation of artificial light and saving energy. Proper daylight harvesting requires the artificial light to be dimmed at different levels throughout a room and throughout the day. For example, more dimming of the light source near a window and less further away. Here, an automatic dimming function may save a tremendous amount of energy.

- **Dimming lighting save energy**
  When you dim a light, you save up to 80 percent in energy and up to about 20% on your energy bill. Dimmer fade your lighting to a preset level. You have total control over how much lighting is used in a room. Dimmer switches can increase annual savings more in your office and building applications. When you reduce the lighting wattage, you have less wear and tear on the lighting which makes the life of the lighting longer.

- **Longevity of Dimming lighting**
  The LED lighting can last longer when you use a dimmer to keep them lit. If you dim the lights by at least 25%, you will save approximately 1/5 of the electricity required. The softer the lamp fade, the longer the lamp lasts. If you keep using the LED lighting fixture products in the dimming method, the products can last more than 5 years.

- **Lighting Controls**
  You can control the dimmer light switch with a knob or by sliding the switch up and down. These days with the more modern dimmer light switches, you can control the amount of lighting with remote control. Touch dimmers give you a change of lighting just by pressing a button. You can set the mood for any room that has the adjusted dimmer light switched lighting. You can use dimmer switch lighting in living rooms, bedrooms, bathrooms, and breakfast nooks.

- **Adjustable Ambience**
  Lighting sets the ambiance of the room, and that is why every room needs to have multiple lighting levels. Dimmer switches are a quick and cost-effective way of offering multiple lighting levels in rooms that have a limited amount of lighting arrangements. Installing adjustable dimmer switches lets the homeowner more accurately set the tone of a room. It also can improve the room's functionality. For instance, you may prefer darker lighting for watching a movie but still want the option of full brightness in that room if you're reading later.

- **Easy Installation**
  A dimmer switch can add a lot of value to your home if properly installed. They are extremely small and can easily fit into a regulation box designed for normal electrical switches. However, before you replace your old switch with a dimmer switch, it is always important to turn off the power of the electrical system.

1.6. Lighting Fixtures

There are some factors we need to consider while selection for LED luminaires is done. There are The criteria are:

- System Luminous Flux & System Luminous Efficacy
- Power Consumption
- CCT
- CRI
- Power Factor
- Housing and Glass or Diffuser material
- Operating Voltage Range
- IP value

- IK value
- Surge protector
- LED chip lifetime (LM80 Report)
- Certification

These are some specific criteria that may help to choose better-LED luminaires.

1.6.1. System Luminous Flux & System Luminous Efficacy

Color performance relative to natural light is sometimes important for aesthetic use. This affects the wavelength range in which the light source should operate. Human eyes were unable to detect radiation outside of the visible wavelength (400-700 nm). Some wavelengths are more sensitive to the eyes than others, even within this range.

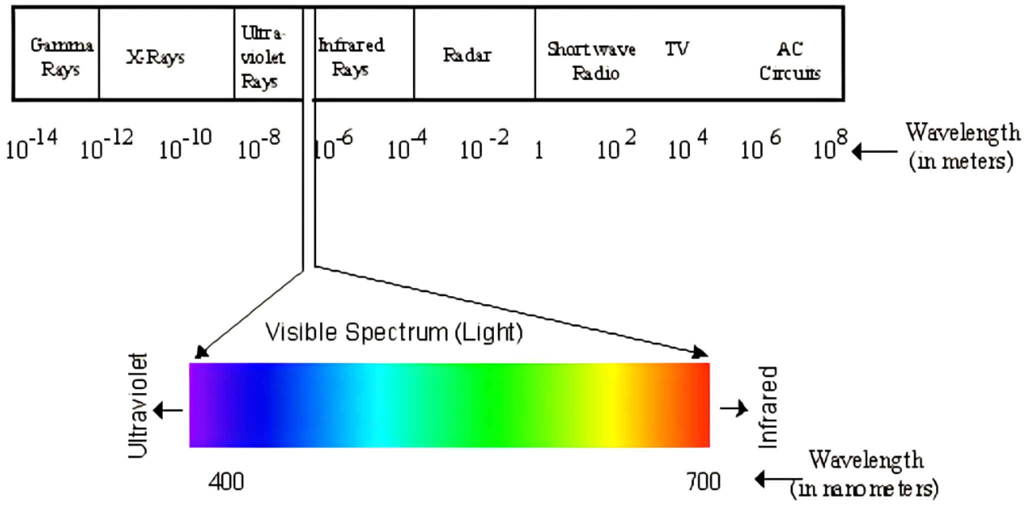


Figure 16: The standardized response of a typical human eye to light is shown

The ratio between the lumens (lm) associated with a given optical power, weighted by the human eye response over wavelength and the electrical source power used to create the optical power (W). Luminous efficacy represents the amount of emitted visible light (also known as luminous flux) in correlation to the input power used. In terms of visible wavelength. The ability of the light source to generate radiation. If the light source emits more wavelengths outside the visible wavelength range, it will lower the luminous flux in proportion to the radian flux. Hence, the luminous efficacy would also be reduced.
Power is consumed by a light source that provides a certain amount of radiation. For example, a 90 W light bulb emits 900 lumens. The luminous efficacy of that light bulb would be 900 lumen / 90 W = 10 lm/W.
Luminous efficacy, denoted K, is defined as-

$$K = \frac{\Phi_v}{\Phi_e} = \frac{\int_0^\infty K(\lambda)\Phi_{e,\lambda}\,d\lambda}{\int_0^\infty \Phi_{e,\lambda}\,d\lambda},$$

Where,

- Φ_v is the luminous flux;
- Φ_e is the radiant flux;
- $\Phi_{e,\lambda}$ is the spectral radiant flux;
- $K(\lambda) = K_m V(\lambda)$ is the spectral luminous efficacy.

Luminous flux radiated by a light source is measured in lumens (lm). The lumen is the SI unit of luminous flux describing the quantity of light emitted by a source or received at a plane. The lumen is derived from the unit of luminous power, the candela (cd). Thus one lumen is the luminous flux emitted within a unit solid angle (one steradian) by a small source having a uniform luminous intensity of one candela, so that 1 lm = 1 cd sr, and the total flux in all directions is

$$4\pi lm.$$

Illuminance (the quantity of illumination) is measured in lux, where 1 lx = 1 lm/sqm. The illumination area also has a direct impact on numerous aspects of the specification and installation, including the beam/tilt angle and distance.

1.6.2. CCT

CCT stands for Correlated Color Temperature. CCT is a technical term used to indicate that the light contains which color that is, a measure of whether the light emitted by the lamp is yellow or blue or any visual color. The unit of measurement is K (Kelvin), and the most common CCT is between 1800K and 6500K. The higher the Kelvin level, the whiter the light.

Figure 17: Different CCTs for the light fixtures

In general, the color temperature of 1800-3000K appears to be a warm light source and has more light in the red, orange, and yellow range. A room for rest or a high-end restaurant that wants to create an atmosphere is suitable for choosing a warm CCT. The cool light source has a higher color temperature (¿4000K), which is expressed as more light in the blue range. In school classrooms and corridors, offices, or hospitals, this refreshing white or blue light will be more needed.

1.6.3. CRI

CRI stands for Color Rendering Index.

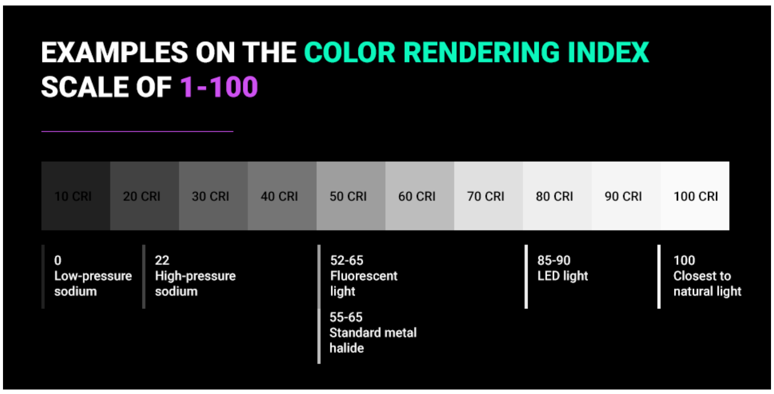


Figure 18: Basic Idea on different CRIs for the light fixtures

Color Rendering Index is the measurement of how colors look under a light source when compared with sunlight. The index is measured from 0-100, with a perfect 100 indicating that colors under the light source appear the same as they would under natural sunlight. This rating is also a measurement in the lighting industry to help discern naturalness, hue discrimination, vividness, preference, color naming accuracy, and color harmony.

Figure 19: Difference between low CRI & high CRI lighting

- Lights with a CRI that is measured greater than 80 are considered to be more than acceptable for most applications.
- Lights with a CRI that is measured greater than 90 are generally considered high CRI lights & used in most places where actual color measures .

1.6.4. IP & IK Ratings

Electric and electronic equipment malfunction when water or dust enters the device. Light fixtures need to have protection from water, dust & impact protection. That's why there are ratings to identify them. These codes are published by the International Electrotechnical Commission (IEC) in a set of guidelines called the IEC 60529. These ratings are widely used throughout the industry. Ingress protection (IP) rating is a grade to measure the resistance of an enclosure against the intrusion of dust or liquids. The IP code consists of two numerals. The first numeral classifies the degree of protection against the ingress of solid foreign bodies (ranging from fingers and tools to fine dust) and protection against access to hazardous parts. The second numeral classifies the degree of protection against the ingress of moisture. The higher the IP values, the better the protection.
The IK rating means the degrees of protection provided by enclosures for electrical equipment against external mechanical impacts or shocks in joules. The IK rating consists of two digits (00 to 10) after the term 'IK' (e.g. IK05). IK ratings are particularly important for lights and lighting fixtures that may be fitted in an area that could be subject to a rough environment attempted vandalism or other impacts. These ratings are also useful for other electrical equipment such as switches or keyboards. IK Rated products are important especially if they are in public areas, high traffic areas, commercial environments, and areas that are prone to vandalism. If a product becomes damaged, this can result in the product failing to work or even failing. The damage leads to additional costs to repair or replace, it also leads to the potential need to close areas to access. A broken product may also lead to a hazard, especially in public areas, such as leftover debris or lack of required illumination/information. Therefore analyzing the risk of an impact is important for deciding if you

need a fixture with a high/low IK Rating. It's worth noting that if it has an IK rating it must also meet the equivalent IP rating. For example, if the enclosure maintains its IP66 rating after passing the test for IK06 protection it can be labeled as both IP66 and IK06. However if after the enclosure passes testing for IK08 protection but only maintains 1p 54 protection, then it must be labeled as IK068 and IP54 protection or IK06 and IP66 but this cannot be labeled as IK08 and IP66 if one test impacts the results of the other.

IP Number	Protection against solid objects	IP Number	Protection against waters
IP 0X	No protection/ No test required	IP X0	No protection/ No test required
IP 1X	Protected against objects greater than 50mm diameter	IP X1	Protected against falling drops of water
IP 2X	Protected against objects greater than 12.5mm diameter, such as a finger	IP X2	Protected against drops falling at 15° in 4 fixed positions
IP 3X	Protected against objects greater than 2.5mm	IP X3	Low pressure spray – similar to shower head at up to 60° from vertical tested using an oscillating tube with an arc of 60° for ten minutes
IP 4X	Protected against objects greater than 1.0mm such as wire	IP X4	Low pressure spray – similar to shower head – as per numeral 3 but 180° for 10 minutes
IP 5X	Ingress of dust is not totally prevented but dust does not enter in harmful quantities to interfere with the correct operation or impair safety	IP X5	Medium pressure jet – 6.3mm diameter, similar to garden hose – from any angle for 3 minutes at a distance of 2.5-3 metres
IP 6X	No ingress of dust permitted	IP X6	High pressure jet – 12.5mm diameter, similar to fire hose – from any angle for 3 minutes at a distance of 2.5-3 meters
IP XY (X indicates protection against solid objects & Y inducates protection against liquids)		IP X7	Immersion – for temporary immersion in water under set conditions – 1 meter for 30 minutes
		IP X8	Protected against the effects of continuous immersion in water, ingress of water in quantities causing harmful effects shall not be possible.

Figure 20: Table for different IP ratings

IK Number	Energy	Equivalent Impact
0	Non-protected	No protection
1	Protected against 0.14 joules impact	Equivalent to impact of 0.25 kg mass dropped from 56 mm above impacted surface
2	Protected against 0.2 joules impact	Equivalent to impact of 0.25 kg mass dropped from 80 mm above impacted surface
3	Protected against 0.35 joules impact	Equivalent to impact of 0.25 kg mass dropped from 140 mm above impacted surface
4	Protected against 0.5 joules impact	Equivalent to impact of 0.25 kg mass dropped from 200 mm above impacted surface
5	Protected against 0.7 joules impact	Equivalent to impact of 0.25 kg mass dropped from 280 mm above impacted surface
6	Protected against 1 joules impact	Equivalent to impact of 0.25 kg mass dropped from 400 mm above impacted surface
7	Protected against 2 joules impact	Equivalent to impact of 0.5 kg mass dropped from 400 mm above impacted surface
8	Protected against 5 joules impact	Equivalent to impact of 1.7 kg mass dropped from 300 mm above impacted surface
9	Protected against 10 joules impact	Equivalent to impact of 5 kg mass dropped from 200 mm above impacted surface
10	Protected against 20 joules impact	Equivalent to impact of 5 kg mass dropped from 400 mm above impacted surface

Figure 21: Table for different IK ratings

1.6.5. Surge Protection

Surge protection is the capability of a system to protect itself against sudden spikes in the net. The requirements, which are set out in the EMC directive for drivers, were relaxed recently. Spikes can lead to situations in which the surge protection of drivers is no longer sufficient to protect the luminaire. This was not a big problem in the past with conventional control gear, but today's increasingly electronic control gear is more vulnerable to these effects. Therefore, more and more OEMs are fitting a separate unit in the luminaire to prevent damage and costly aftersales maintenance.

Chapter: 2
Architectural Lighting

2. Architectural Lighting

2.1. Introduction

Lighting plays a vital role in the way people experience and understand architecture. Whether buildings and structures are lit naturally or artificially, lighting is the medium that allows us to see and appreciate the beauty in the buildings around us. Lighting can bring an emotional value to architecture – it helps create an experience for those who occupy the space. Exterior lighting brings facades and outdoor spaces to life. Whether utilizing fixtures for security, landscape, or dramatic effect, exterior lights can transform how you see and understand a building or pathway, or entrance. For a designer, it's important to understand how outdoor lights can integrate with a building and its larger site. By understanding the play between light and dark, the designer can use contrast and shadows to create inspiring and intriguing spaces. The main starting point when considering exterior lighting is to establish the primary design goal is the designer hoping to identify key features, add drama to surfaces that don't normally stand out, or simply create a clear path and entryway? The designer can both highlight a building's architectural features and draw attention to plantings and trees. From task lighting for safety to ambient string lights for the perfect outdoor party, start by identifying the outdoor spaces you want to use and then find solutions for each area. Next, you should understand the basic types of fixtures when making your lighting plan. Finally security and maintenance. These steps are reviewed while designing a lighting design to provide a solid foundation for understanding different ways to brighten the illuminating field [8].

2.2. Factors of Good Architectural Lighting

Vision is the single most important sense through which we enjoy architecture, and lighting enhances the way we perceive architecture even more. To create a successful balance between lighting and architecture, it's important to remember three key aspects of architectural lighting,

- Aesthetic
- Function &
- Efficiency

2.2.1. Aesthetic

The aesthetic is where designers and architects focus on the emotional impact the balance of lighting and architecture will have on occupants. It's where designers determine how they want people to feel when they walk around a space. This aspect is especially important for retail locations; exterior lighting should draw the consumer in, and the interior lighting should awe them as they walk through the doors in addition to showing off the product.

2.2.2. Function

The second aspect, function, cannot be overlooked. We want the lighting to look a certain way, but we have to also make sure it serves its most important purpose – to help us see. Areas should be illuminated so occupants feel safe when navigating a room or entire building. They should be able to see the floor and walls around them, which should create a feeling of reassurance.

2.2.3. Efficiency

The final aspect is very important in today's age of green building and sustainability movements. It's one thing to create a breath-taking lighting layout, but it's another to create a breath-taking layout that is also incredibly energy efficient. This can be done by assuring the majority of the light is reaching its target and there is less wasted light. Reducing the amount of wasted light will make the building more efficient. An easy way this can be done is to install LEDs instead of fluorescent lighting. Because of the technology, there is less wasted light with LEDs than with fluorescent due to the directional nature of LEDs.

2.3. Light sources in Architectural Lighting

- **Wall Lights:** The classic front or back porch light, wall lights can be mounted on virtually any vertical surface. One of the most commonly seen outdoor fixtures, wall lights is durable and attractive. Outdoor wall lights are usually used for decorative purposes, providing ambient or accent lighting rather than focused, bright lighting. These are the ideal choice for patios or porches.

- **Path Lights:** This is the most common type of landscape lighting. Path lights are small posts that have a light built in and are capped with a diffuser. They can be used to frame out a space or feature in a yard or spread out down a walkway. They can be placed around a pond, along a driveway, or lining a pathway.

- **Landscape Lights:** Landscape lighting is a low voltage system separate from the wall and ceiling lights. Path, spot, and floodlights can be used in combination to create layered lighting. Spotlights can be used for featuring several outdoor elements like trees, buildings, and sculptural and architectural details. Wall lights are recessed into the ground to create a seamless look in both landscape and hardscape settings. The inset profile is minimal and can be used to light trees, walls, or art.

- **Ceiling Lights & Hanging Lights:** Ceiling lights and hanging lights are usually selected for damp locations where they're never directly exposed to rain. Made to be integrated into a surface or as a featured light, they are normally specified as brighter fixtures. You can find hanging lights in a wide range of styles that offer varying levels of brightness.

- **Post Lights & Pier Mount Lights:** As the name suggests, post lights are fixtures that mount on top of posts. When more architectural light is needed, post mount lights are designed to install onto a post or on top of a structure. They're commonly used for entries, gates, fences, or around a deck. Because they're usually placed in open-air settings like driveways and pathways, most post lights are "wet rated," meaning they are designed to withstand direct exposure to rain and moisture. Pier mount lights look much like post lights but are designed to be installed on top of columns or walls.

- **Deck and Step Lights:** Deck and step lights are installed directly into a yard's hardscape or decking. They are used as an accent to architectural details and added safety to dark stairs. They can also be used for washing light down stone walls or lighting up entertainment spaces.

Chapter: 3
Software Simulation

3. Design Parameters & Software Simulation

3.1. Introduction

Simulation software is based on the process of modeling a real phenomenon with a set of mathematical formulas. It is, essentially, a program that allows the user to observe an operation through simulation without actually performing that operation. Simulation software is used widely to design equipment so that the final product will be as close to design specs as possible without being expensive in process modification. Simulation software with the real-time response is often used in 3D Modeling, it also has important industrial applications. In theory, any phenomena that can be reduced to mathematical data and equations can be simulated on a computer. Simulation can be difficult because most natural phenomena are subject to an almost infinite number of influences. One of the tricks to developing useful simulations is to determine which are the most important factors that affect the goals of the simulation. In addition to imitating processes to see how they behave under different conditions; simulations are also used to test new theories. After creating a theory of causal relationships, the theorist can codify the relationships in the form of a computer program. If the program then behaves in the same way as the real process, there is a good chance that the proposed relationships are correct [8].

3.2. Design Parameters for a Good Temple Lighting

The lighting scheme should be such that it can,

- Provide adequate illumination,
- Provide light distribution all over the illuminating plane as uniform as possible,
- Power management & fixing of the light fixtures,
- Beam angle of the fixtures,
- Provide light of suitable color, &
- Avoid glare and hard shadows as far as possible.

For any kind of lighting design, these parameters need to be considered.

Figure 22: Site images of the temple chosen for this thesis

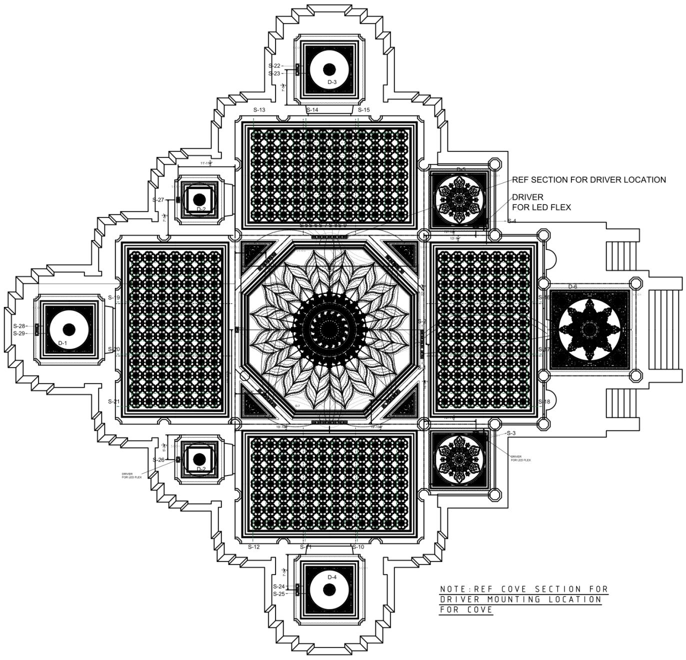


Figure 23: Above image is the Floor Plan of the Temple

3.2.1. Reason Behind Choosing CCT

Artificial lighting is a versatile tool that can be utilized to transform a space. It can be used in public areas to enhance performance and worship productions or within private establishments as functional or decorative lighting solutions. A survey of lighting professionals concluded that color is a critical consideration in all lighting applications and that it is typically more important than light efficacy. The stones used in the temple are light beige, basically a little yellowish white & brown mix color. To expose the beautiful craftsmanship in the walls, golden color is used. To segregate different areas two types of similar CCT are chosen for this design. In this design CCT of 1800K & 2200K was used.

3.2.2. Reason Behind Choosing of Different Beam Angle

When designing any lighting design the designer needs to mind the amount of light loss. The minimum the light loss, the better the lighting design will be. To control the light loss factor in the outdoor design beam angle of the fixture plays a vital role [8]. There are mainly 2 types of light beam angles: symmetrical and asymmetrical. There is also another beam angle called double asymmetrical, which is widely used in flood lights. This technical feature plays a key role in creating the optimum lighting effect in application areas such as stadiums, theatres, landscapes, sports arenas, or streets. The main advantage of asymmetrical beams is order to maximize the light output and unlock the full potential of light. Symmetrical light sources distribute light evenly in all directions. This type of light beam is recommended for both general lightings of large spaces and accent lighting for visual tasks. On the other hand, asymmetrical lighting is ideal for concentrating the light beam in one direction. Therefore, it can be an efficient solution for facade lighting design as it does not produce direct glare that can cause eyestrain with protracted exposure. Glare occurs when the eye encounters more light than it can cope with. Luminance is light reflected from an illuminated surface, such as a white piece of paper or stainless-steel workbench, which needs to be considered. Similarly, too much contrast or shadow can make it difficult to see properly to complete a task. These are all factors that can be taken into consideration in lighting design to help plan the right product selection and placement.

3.2.3. Issues that have been handled for Installation

The temple designed in this project is located near the sea shore. As all the extrusions are used aluminum it's very vital to choose the perfect coating to protect from the sea salt present in the air. It's known to all that salt water doesn't tend to play nice with any kind of metal. Despite of that for boating purposes, people prefer aluminum bodies for boats. The effect of salt water on aluminum will be corrosion. People tend to mix in between corrosion & rust. But they both are different. In corrosion, the metal wears off as a result of a chemical reaction. Aluminum doesn't contain any iron or steel, that's why it won't get rust. Aluminum is also known for its ability to resist corrosion well under some circumstances. When aluminum corrodes a thin layer of aluminum oxide is created. By that, a protected shield is created that inhibits further corrosion. However salts are extremely corrosive, that's

Figure 24: Difference between symmetrical or asymmetrical beam angle wash lights

why when salt air comes into contact with aluminum it can cause a chalky, white coating of aluminum oxide & an unpleasant pitting. To prevent the extrusions in this project have the marine coating in a matte finish, which has both corrosion resistive & scratchproof, which will be long-lasting (for at least) 5 years without corrosion.

3.2.4. Controlling Technique

For this lighting design, a DALI control system is used. On the site total of 6 no's of the electrical panel is considered for a total of 30KW load. For connection of these lights, 4 Core Aluminium Armoured Cable is considered with 350W Meanwell constant voltage driver.

DALI Control:

Lighting controls are a type of smart lighting technology that allows you to adjust the amount, quality, and characteristics of light in a specific area. Dimers are a good example of lighting controls. For this design DALI controlling can be considered as dimming control and looking for a way to power savings. DALI stands for Digital Addressable Lighting Interface. It is a 2-way communications protocol that is used to provide control over, and communication between, the components in a lighting system. The current (2020) version of DALI is called DALI-2 and this is defined in IEC62386 [9].

Key features of DALI:

- It is an open protocol – any manufacturer can use it.
- With DALI-2 interoperability between manufacturers is guaranteed by mandatory certification procedures.
- Installation is simple. Power and control lines can be laid together and no shielding is required.
- The wiring topology can be in the form of a star (hub & spoke), a tree or a line, or any combination of these.
- Communication is digital, not analog, so the same dimming values can be received by multiple devices resulting in very stable and precise dimming performance.
- DALI is addressable. This opens the way for many valuable features such as grouping, scene-setting, and dynamic control, such as changing which sensors and switches control which light fittings in response to office layout changes.
- DALI is digital, not analog. This means that DALI can offer much more precise light level control and more consistent dimming.
- DALI is a standard, so, for example, the dimming curve is standardized meaning that equipment is interoperable between manufacturers.

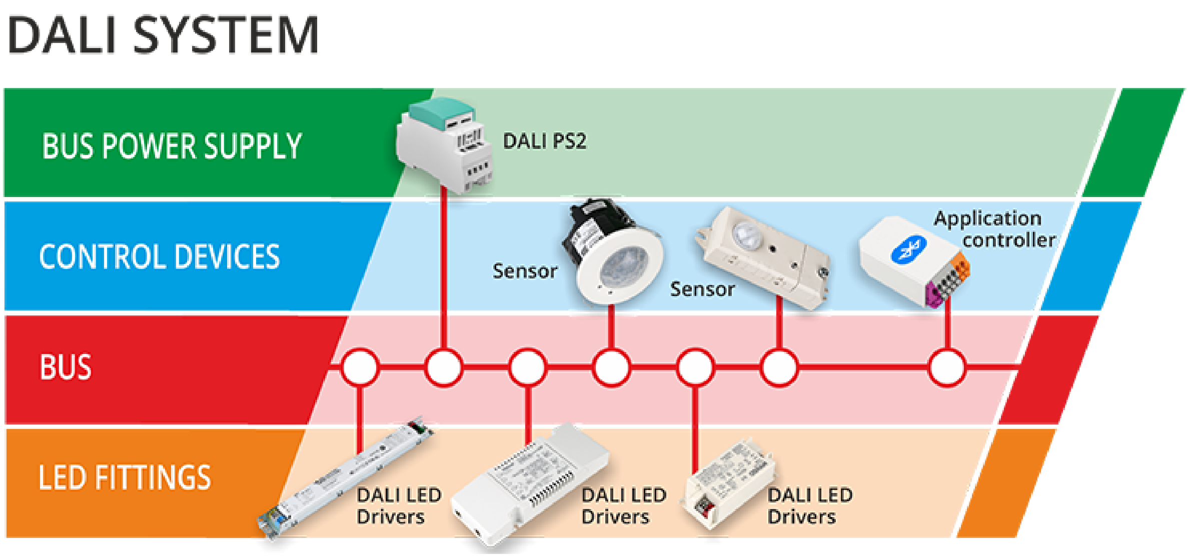


Figure 25: Dali System

The core of DALI is a bus – a pair of wires that carries digital control signals from input devices (such as sensors), to an application controller. The application controller applies the rules with which it has been programmed to generate outgoing signals to devices such as LED drivers.

- **Bus power supply unit (PSU):** This component is always required. It maintains the bus voltage at the required level.

- **Led Fittings:** All light fittings in a DALI installation require a DALI driver. A DALI driver can accept DALI commands directly from the DALI bus and respond accordingly. The drivers can be DALI or DALI-2 devices, but if they are not DALI-2 they will not have any of the new features introduced with this latest version.
- **Input Devices:** Input devices – sensors, switches, etc. These communicate with the application controller using 24-bit data frames. They do not communicate directly with the control devices.
- **Control devices:** The controller is the brain of the system. It receives 24-bit messages from the sensors (etc.) and issues 16-bit commands to the control gear. The application controller also manages the data traffic on the DALI bus, checking for collisions and re-issuing commands as necessary.

For this project below Dali system is used:
For the dimming process, I've created 5 separate control groups, which can illuminate the

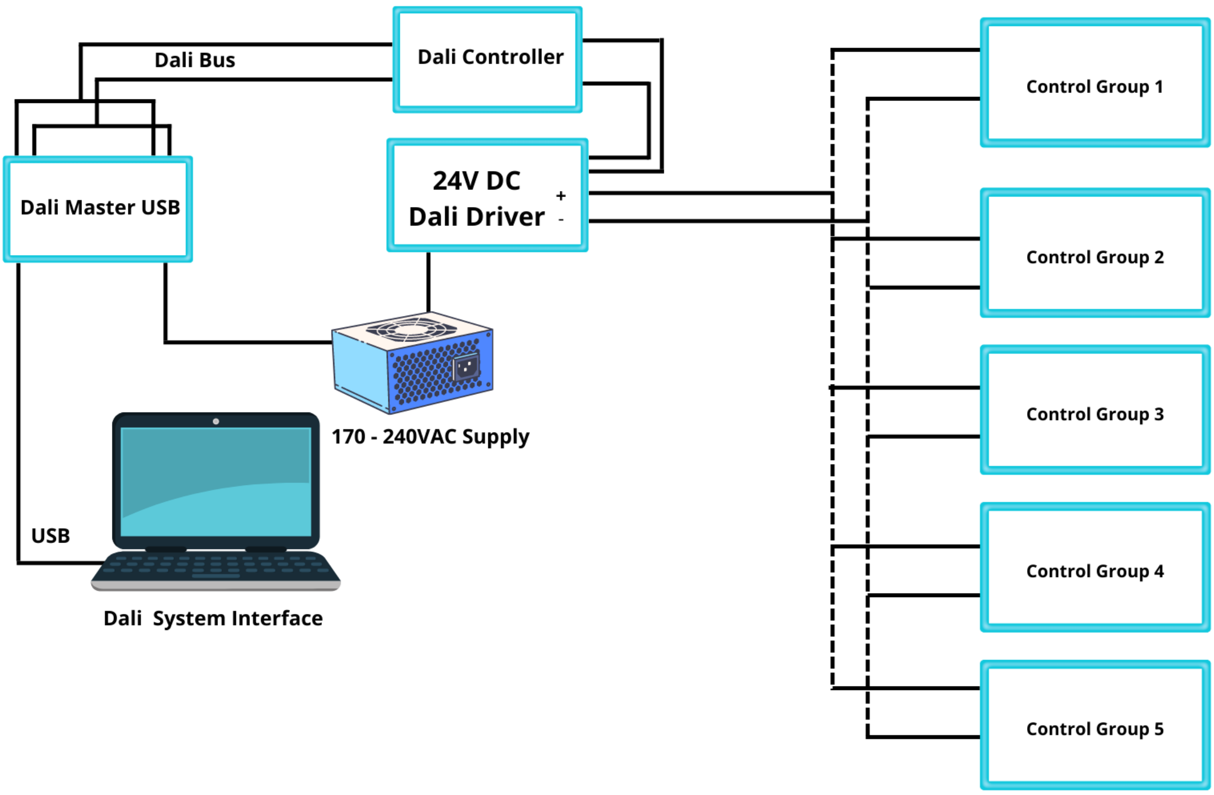


Figure 26: Dali System Connection Diagram Used for this Project

temple step by step. The simulated images will be later on in this thesis.

Another lighting control can be defined here which is DMX (Digital Multiplexing) control. If the fixtures can be connected with the control receiver which is directly connected with the DMX controller. Some wireless receivers are here nowadays to control the lighting fixtures remotely. Another possible thing can be done for DMX control. For that PCB modification is required, In the IC needs to be connected with the LED & then simply have to connect with the decoder to control the lights.

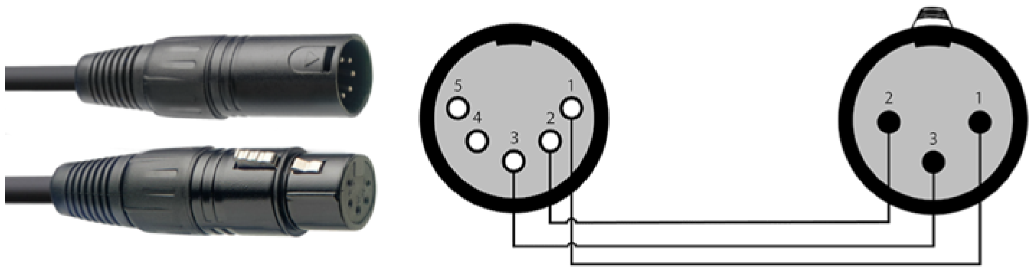


Figure 27: XLR male, XLR female connectors

XLR connectors are vastly used for DMX controlling. With these connectors lighting fixtures can be connected. These connectors are used for Master & Slave control for the lighting fixtures.

3.3. Luminaires used for this 3DS Max Software Simulation

Figure 28: 50W Single Color Wash Light

Specifications

- Die-cast aluminum alloy Housing in grey powder coating finish.
- Toughened Glass with IK08 Protection.
- Pre-wired for loop-in & loop-out connector and accessories.
- Provided aluminum extruded yoke to fix the lights.
- Ingress Protection: IP 67
- All screws are A2 stainless steel.

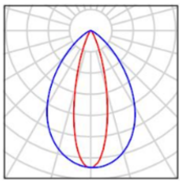
Electrical Parameters

- Operating Voltage: 24 Volt
- 3V, 3535 SMD LED
- CCT used 1800K, 2200K
- Beam Angle: 30° x 60°
- Luminaire Rated Power: 50 Watt
- Average Life: L70@50000 hours

- Light output per lamp: 5550 Lumen
- Lamp Luminous Efficacy: 110 Lumen/Watt
- CRI is higher than 85

Leksa Lighting Technologies PVT.LTD LK IP W 50 Wall / Ceiling-mounted Wash, 1800K, 30 degrees x 60 degrees
Article No.: LK IP W 50
Luminous flux (Luminaire): 5500 lm
Luminous flux (Lamps): 5500 lm
Luminaire Wattage: 50.0 W
Luminaire classification according to CIE: 100
CIE flux code: 87 98 100 100 10
Fitting: 1 x LED Amber (Correction Factor 1.000).

See our luminaire catalog for an image of the luminaire.



Leksa Lighting Technologies PVT.LTD LK IP W 50 Wall / Ceiling-mounted Wash, 2200K, 30 degrees x 60 degrees
Article No.: LK IP W 50
Luminous flux (Luminaire): 5500 lm
Luminous flux (Lamps): 5500 lm
Luminaire Wattage: 50.0 W
Luminaire classification according to CIE: 100
CIE flux code: 87 98 100 100 10
Fitting: 1 x LED Golden (Correction Factor 1.000).

See our luminaire catalog for an image of the luminaire.

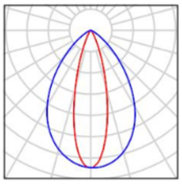


Figure 29: Luminaire parts list for 50W Wash Light in 1800K & 2200K CCT

Figure 30: 36W 2 Feet Linear Wash

Specifications

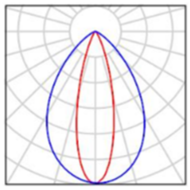
- Die-cast aluminum alloy Housing in grey powder coating finish.
- Toughened Glass with IK08 Protection.
- Pre-wired for loop-in & loop-out connector and accessories.
- Provided aluminum extruded yoke to fix the lights.
- Ingress Protection: IP 67
- All screws are A2 stainless steel.

Electrical Parameters

- Operating Voltage: 24 Volt
- 3V, 3535 LED
- CCT: 1800K, 2200K
- Beam Angle: 20° x 60°, 30°
- Luminaire Rated Power: 36 Watt
- Average Life: L70@50000 hours
- Light output per lamp: 3780 Lumen
- Lamp Luminous Efficacy: 105 Lumen/Watt
- CRI is higher than 85

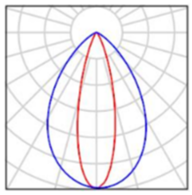
Leksa Lighting Technologies PVT.LTD LK IP LW 36 Wall / Ceiling-mounted Linear Wash, 1800K, 30 degrees x 60 degrees
Article No.: LK IP LW 36
Luminous flux (Luminaire): 3000 lm
Luminous flux (Lamps): 3000 lm
Luminaire Wattage: 36.0 W
Luminaire classification according to CIE: 100
CIE flux code: 87 98 100 100 36
Fitting: 1 x LED Amber (Correction Factor 1.000).

See our luminaire catalog for an image of the luminaire.



Leksa Lighting Technologies PVT.LTD LK IP LW 36 Wall / Ceiling-mounted Linear Wash, 2200K, 30 degrees x 60 degrees
Article No.: LK IP LW 36
Luminous flux (Luminaire): 3000 lm
Luminous flux (Lamps): 3000 lm
Luminaire Wattage: 36.0 W
Luminaire classification according to CIE: 100
CIE flux code: 87 98 100 100 36
Fitting: 1 x LED Golden (Correction Factor 1.000).

See our luminaire catalog for an image of the luminaire.



Leksa Lighting Technologies PVT.LTD LK IP LW 36 Wall / Ceiling-mounted Linear Wash, 2200K, 30 degrees
Article No.: LK IP LW 36
Luminous flux (Luminaire): 3000 lm
Luminous flux (Lamps): 3000 lm
Luminaire Wattage: 36.0 W
Luminaire classification according to CIE: 100
CIE flux code: 87 98 100 100 36
Fitting: 1 x LED Golden (Correction Factor 1.000).

See our luminaire catalog for an image of the luminaire.

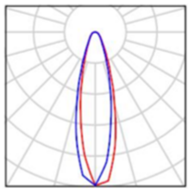


Figure 31: Luminaire parts list for 2 Feet Linear Wash Light in 1800K & 2200K CCT

Figure 32: 18W 1 Feet Linear Wash

Specifications

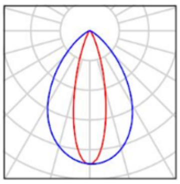
- Die-cast aluminum alloy Housing in grey powder coating finish.
- Toughened Glass with IK08 Protection.
- Pre-wired for loop-in & loop-out connector and accessories.
- Provided aluminum extruded yoke to fix the lights.
- Ingress Protection: IP 67
- All screws are A2 stainless steel.

Electrical Parameters

- Operating Voltage: 24 Volt
- 3V, 3535 SMD LED
- CCT used 1800K, 2200K
- Beam Angle: 30° x 60°
- Luminaire Rated Power: 18 Watt
- Average Life: L70@50000 hours
- Light output per lamp: 1980 Lumen
- Lamp Luminous Efficacy: 110 Lumen/Watt
- CRI is higher than 85

Leksa Lighting Technologies PVT.LTD LK IP LW 18 Wall / Ceiling-mounted Linear Wash, 1800K, 30 degrees x 60 degrees
Article No.: LK IP LW 18
Luminous flux (Luminaire): 1980 lm
Luminous flux (Lamps): 1980 lm
Luminaire Wattage: 18.0 W
Luminaire classification according to CIE: 100
CIE flux code: 87 98 100 100 28
Fitting: 1 x LED Amber (Correction Factor 1.000).

See our luminaire catalog for an image of the luminaire.



Leksa Lighting Technologies PVT.LTD LK IP LW 18 Wall / Ceiling-mounted Linear Wash, 2200K, 30 degrees x 60 degrees
Article No.: LK IP LW 18
Luminous flux (Luminaire): 1980 lm
Luminous flux (Lamps): 1980 lm
Luminaire Wattage: 18.0 W
Luminaire classification according to CIE: 100
CIE flux code: 87 98 100 100 28
Fitting: 1 x LED Golden (Correction Factor 1.000).

See our luminaire catalog for an image of the luminaire.

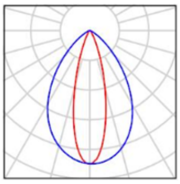


Figure 33: Luminaire parts list for 1 Feet Linear Wash Light in 1800K & 2200K CCT

Figure 34: 50W 1 Meter Linear Wash

Specifications

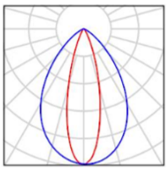
- Die-cast aluminum alloy Housing in grey powder coating finish.
- Toughened Glass with IK08 Protection.
- Pre-wired for loop-in & loop-out connector and accessories.
- Provided aluminum extruded yoke to fix the lights.
- Ingress Protection: IP 67
- All screws are A2 stainless steel.

Electrical Parameters

- Operating Voltage: 24 Volt
- 3V, 3535 LED
- CCT: 1800K, 2200K
- Beam Angle: 30° x 60°, 30°
- Luminaire Rated Power: 50 Watt
- Average Life: L70@50000 hours
- Light output per lamp: 3600 Lumen
- Lamp Luminous Efficacy: 72 Lumen/Watt
- CRI is higher than 85

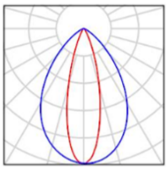
Leksa Lighting Technologies PVT.LTD LK IP LW 50 Wall / Ceiling-mounted Linear Wash, 1800K, 30 degrees x 60 degrees
Article No.: LK IP LW 50
Luminous flux (Luminaire): 3600 lm
Luminous flux (Lamps): 3600 lm
Luminaire Wattage: 50.0 W
Luminaire classification according to CIE: 100
CIE flux code: 87 98 100 100 15
Fitting: 1 x LED Amber (Correction Factor 1.000).

See our luminaire catalog for an image of the luminaire.



Leksa Lighting Technologies PVT.LTD LK IP LW 50 Wall / Ceiling-mounted Linear Wash, 2200K, 30 degrees x 60 degrees
Article No.: LK IP LW 50
Luminous flux (Luminaire): 3600 lm
Luminous flux (Lamps): 3600 lm
Luminaire Wattage: 50.0 W
Luminaire classification according to CIE: 100
CIE flux code: 87 98 100 100 15
Fitting: 1 x LED Golden (Correction Factor 1.000).

See our luminaire catalog for an image of the luminaire.



Leksa Lighting Technologies PVT.LTD LK IP LW 50 Wall / Ceiling-mounted Linear Wash, 2200K, 30 degrees
Article No.: LK IP LW 50
Luminous flux (Luminaire): 3600 lm
Luminous flux (Lamps): 3600 lm
Luminaire Wattage: 50.0 W
Luminaire classification according to CIE: 100
CIE flux code: 87 98 100 100 15
Fitting: 1 x LED Golden (Correction Factor 1.000).

See our luminaire catalog for an image of the luminaire.

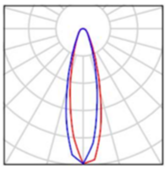


Figure 35: Luminaire parts list for 1 Meter Linear Wash Light in 1800K & 2200K CCT

Figure 36: 15W 1 Meter Corner Profile

Specifications

- Aluminium Profile
- Milky White diffuser
- Pre-wired for loop-in & loop-out connector and accessories
- Provided stainless steel clips to fix the lights
- Ingress Protection: IP 67

Electrical Parameters

- Operating Voltage: 24 Volt
- 3V, 3535 LED
- CCT: 2700K
- Beam Angle: 120°
- Luminaire Rated Power: 15 Watt
- Average Life: L70@50000 hours
- Light output per lamp: 1500 Lumen
- Lamp Luminous Efficacy: 100 Lumen/Watt
- CRI is higher than 90

Figure 37: 15W 1 Meter Side Bend Flexible Strip

Specifications

- Silicone Extrusion
- Milky White diffuser on top
- Pre-wired for loop-in & loop-out connector and accessories
- Provided stainless steel clips to fix the lights
- Ingress Protection: IP 67

Electrical Parameters

- Operating Voltage: 24 Volt
- 3V, 3535 LED
- CCT: 2200K
- Beam Angle: 120°
- Luminaire Rated Power: 15 Watt
- Average Life: L70@50000 hours
- Light output per lamp: 1125 Lumen
- Lamp Luminous Efficacy: 75 Lumen/Watt
- CRI is higher than 85

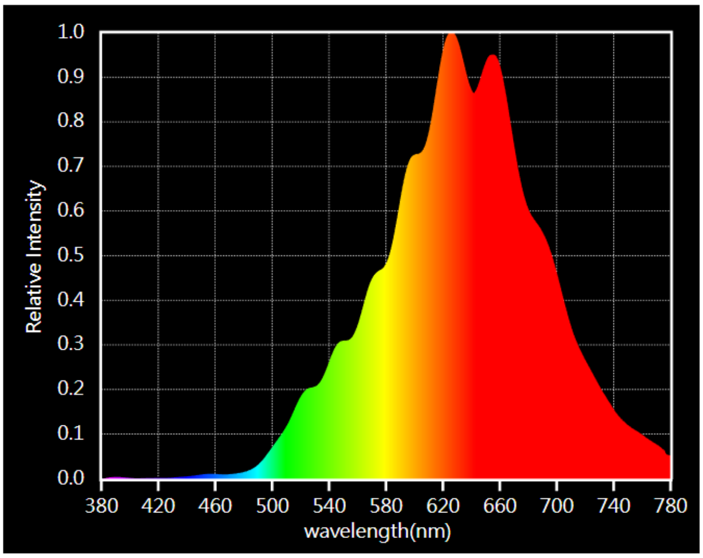


Figure 38: Spectrum of 1800K CCT Fixtures

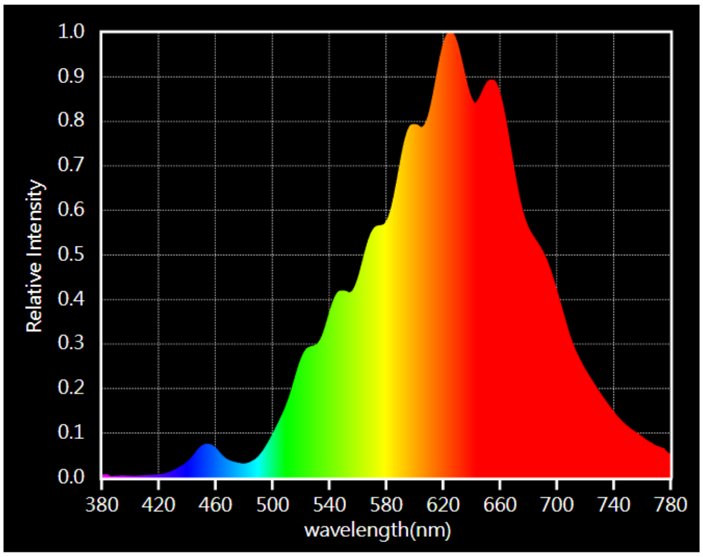


Figure 39: Spectrum of 2200K CCT Fixtures

3.3.1. BOQ of the Luminaires used for this Temple Lighting

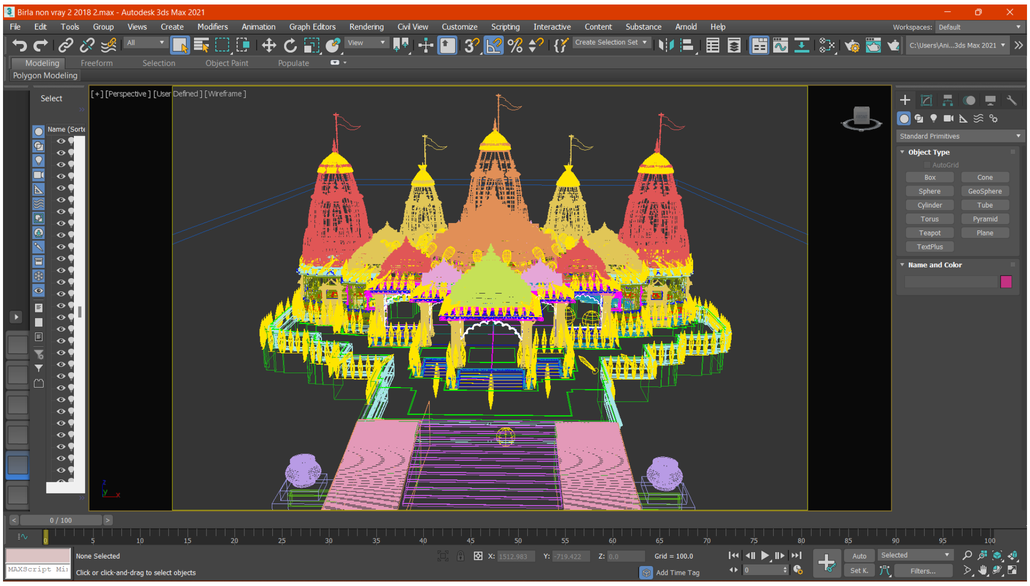
Sl No.	Fixture Type	CCT	Wattage (W)	Beam Angle	Qty	Unit	Total Wattage (W)
1	Wash Light	1800K	50	30° x 60°	80	Nos	4000
2	Wash Light	2200K	50	30° x 60°	140	Nos	7000
3	1 Feet Linear Wash	1800K	18	30° x 60°	70	Nos	1260
4	1 Feet Linear Wash	2200K	18	30° x 60°	130	Nos	2340
5	2 Feet Linear Wash	1800K	36	30° x 60°	50	Nos	1800
6	2 Feet Linear Wash	2200K	36	30°	15	Nos	540
7	2 Feet Linear Wash	2200K	36	30° x 60°	30	Nos	1080
8	1 Meter Linear Wash	1800K	50	30° x 60°	14	Nos	700
9	1 Meter Linear Wash	2200K	50	30°	10	Nos	500
10	1 Meter Linear Wash	2200K	50	30° x 60°	25	Nos	1250
11	1 Meter Corner Profile	1800K	15	120°	312	Mtrs	4680
12	Side Bend Flexible Strip	2200K	15	120°	67	Mtrs	1005
						Total Wattage:	26155

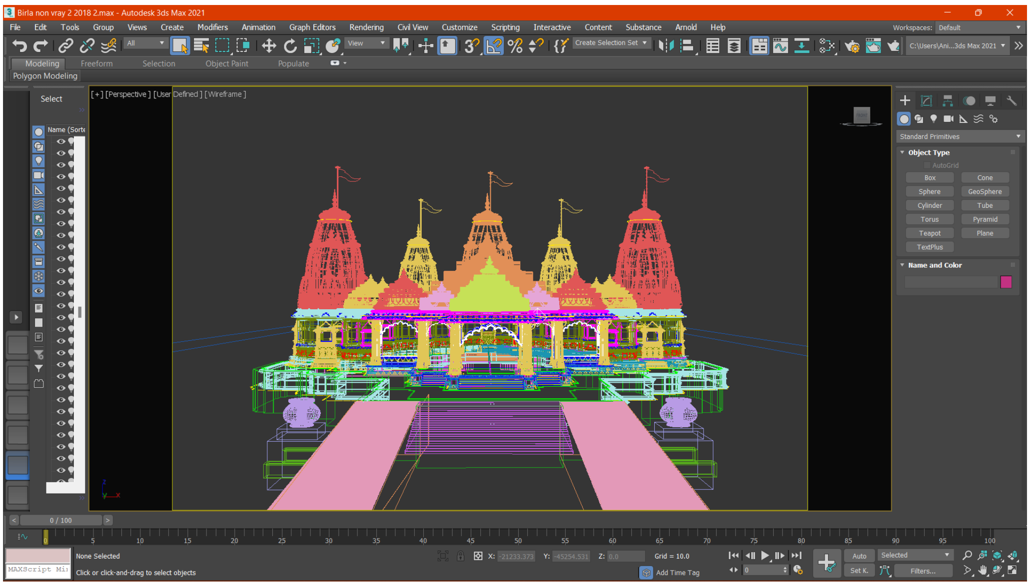
A total of 26155 W power consumption will be done for the lighting part of this temple. In the panel box total of 30KW power consumption is considered. A total of 85 No's of the driver is considered for this project which is divided into 6 power panels.

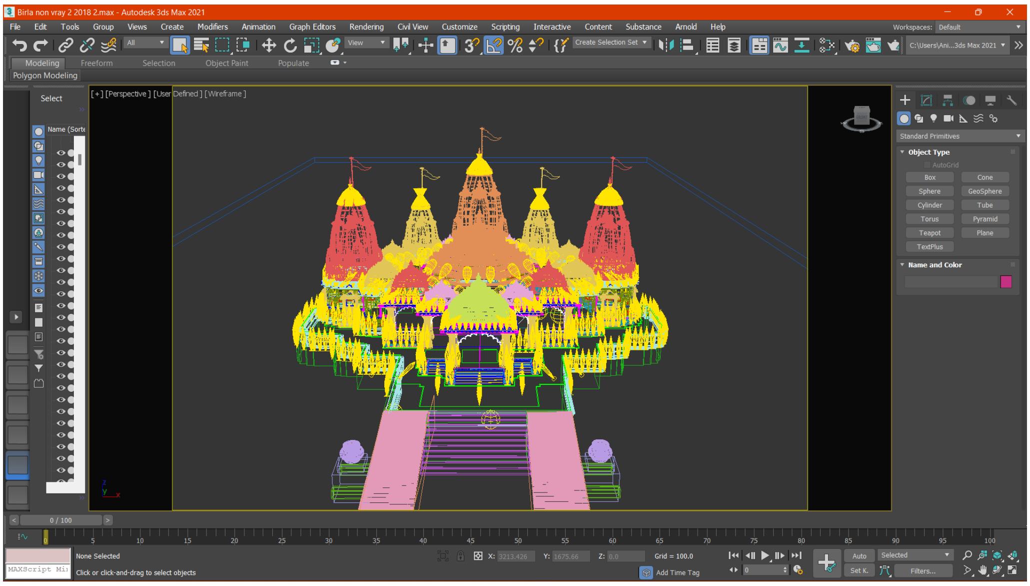
3.4. 3DS Max Software Simulation

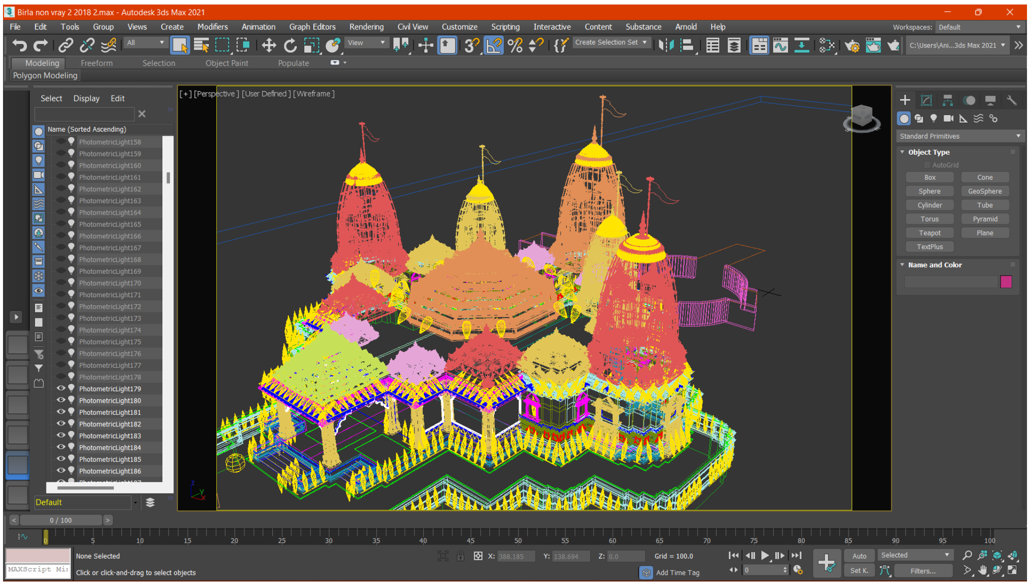
To conduct the simulation for my project, I used 3DS Max software. 3DS Max software is used by professionals doing 3D design in architectural design. The Lighting Designers are used to plan, calculate & visualize light for indoor and outdoor areas like indoor lighting, area lighting & facade lighting simulations where aesthetic visualization is most important. Many areas can be designed satisfactorily through this software.

3.4.1. 3DS Max Software Simulation Walkthrough









As per the floor plan given by the client, a 3D model is created for the temple for proposing the lighting solution of the sample. Above all Four Above images are screenshots taken in the 3DS Max Software from various directions.

Figure 40: Above image is a screenshot taken in the 3DS Max Software after Rendering (This is the front side of the temple) Corner Profile of 1800K CCT is used

This image represents the stairs of the temple (from the front). For illuminating this I have used corner profile of 1800K CCT as per the required dimensions for giving the effect of continuous lighting effect. The lights are set up under the staircase with the help of an SS clamp. The L shape of this profile gives the directional output to the staircase which helps to properly illuminate with amber color.
For controlling these lights with the DALI controller this set is considered “ Group 1”.

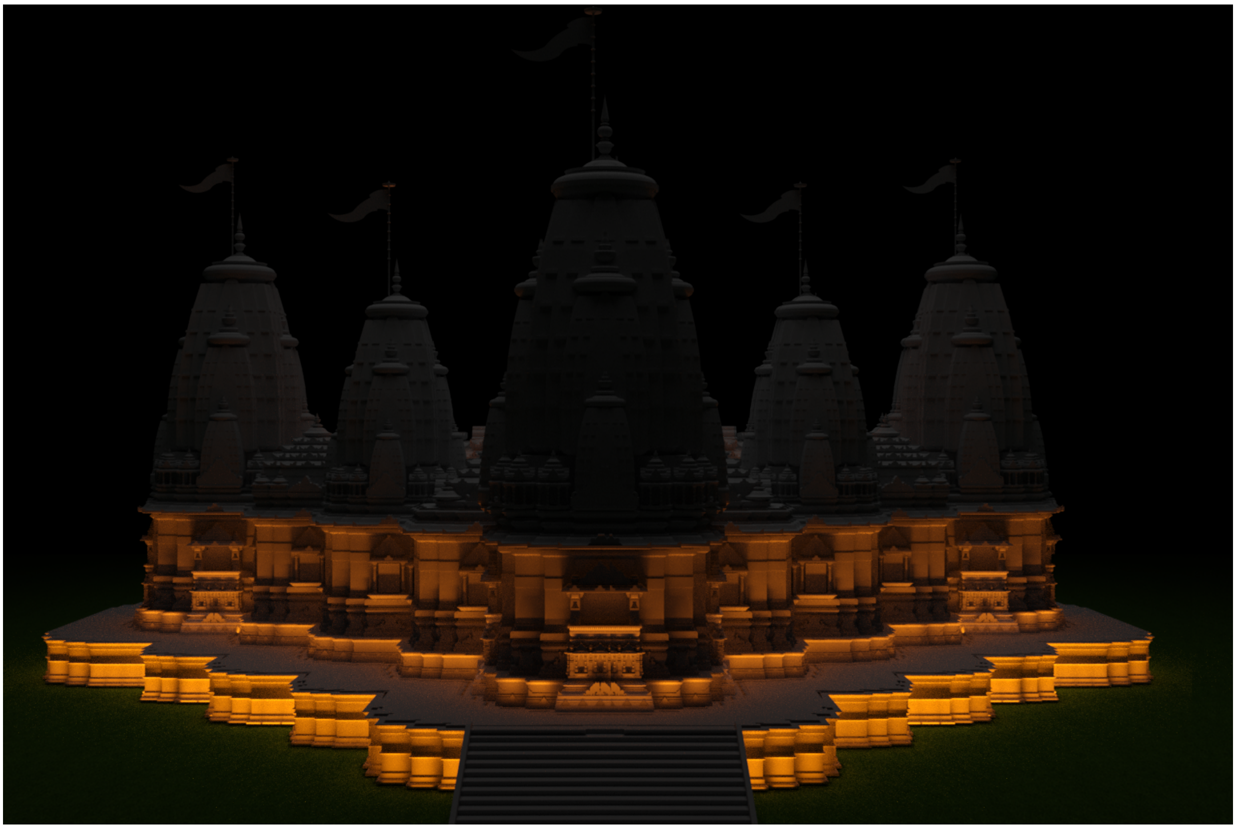


Figure 41: Above image is a screenshot taken in the 3DS Max Software after Rendering (This is the front side of the temple)

This image represents the pilers of the temple (from the front). For illuminating this I have used 1 foot linear wash & 1 meter linear wash of 1800K CCT for giving the lighting effect. The lights are set up with the yoke by screwing the floor. As the lights are set up beside the path of the temple, the beam angle is chosen as asymmetrical to minimize the glare to the visitors and also maintain the light output.
For controlling these lights with the DALI controller this set is considered " Group 2".

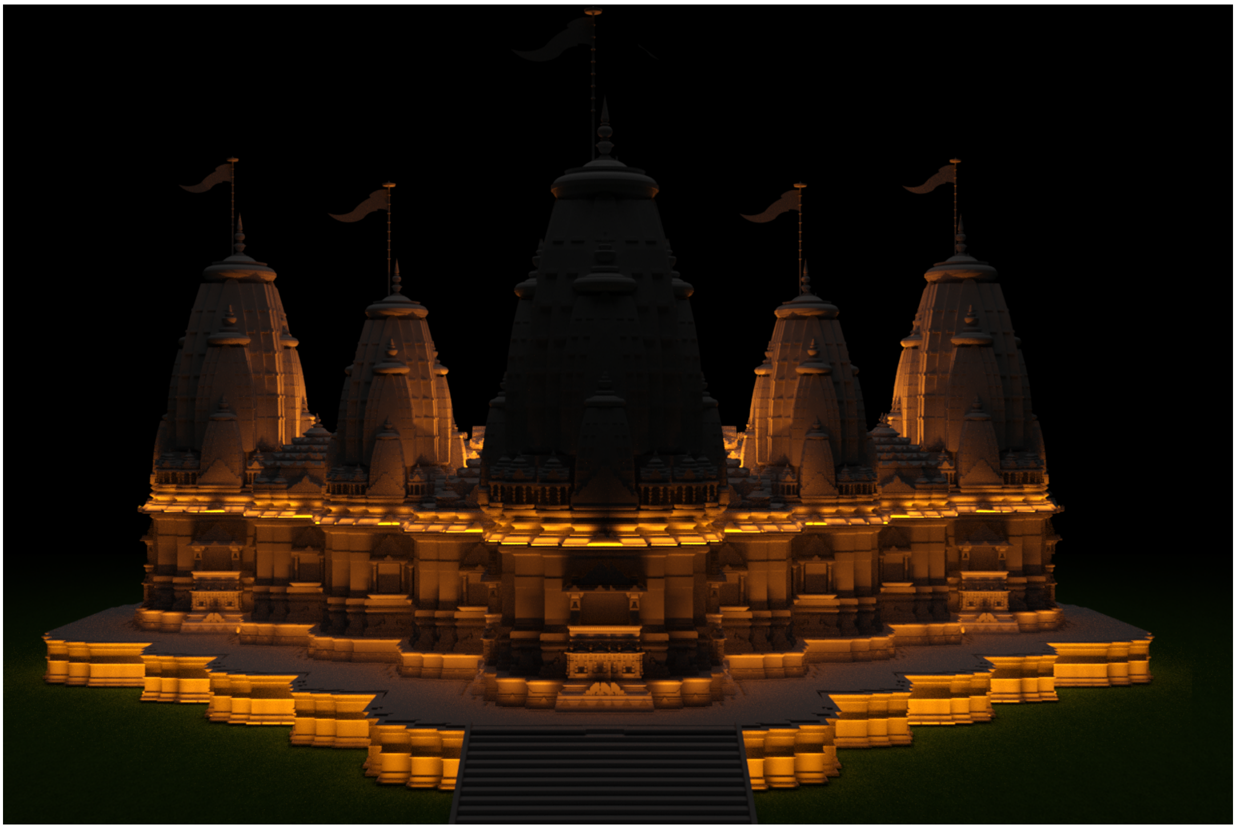


Figure 42: Above image is a screenshot taken in the 3DS Max Software after Rendering (This is the front side of the temple)

This image represents the pilers of the temple (from the front). For illuminating this I have used 1 foot linear wash & 2 feet linear wash of 2200K CCT for giving the lighting effect. The lights are set up with the yoke by screwing the wall. This 2200K CCT gives a more golden vibe to segregate & showcase the craftmanship on the wall of the temple.
For controlling these lights with the DALI controller this set is considered “ Group 3”.

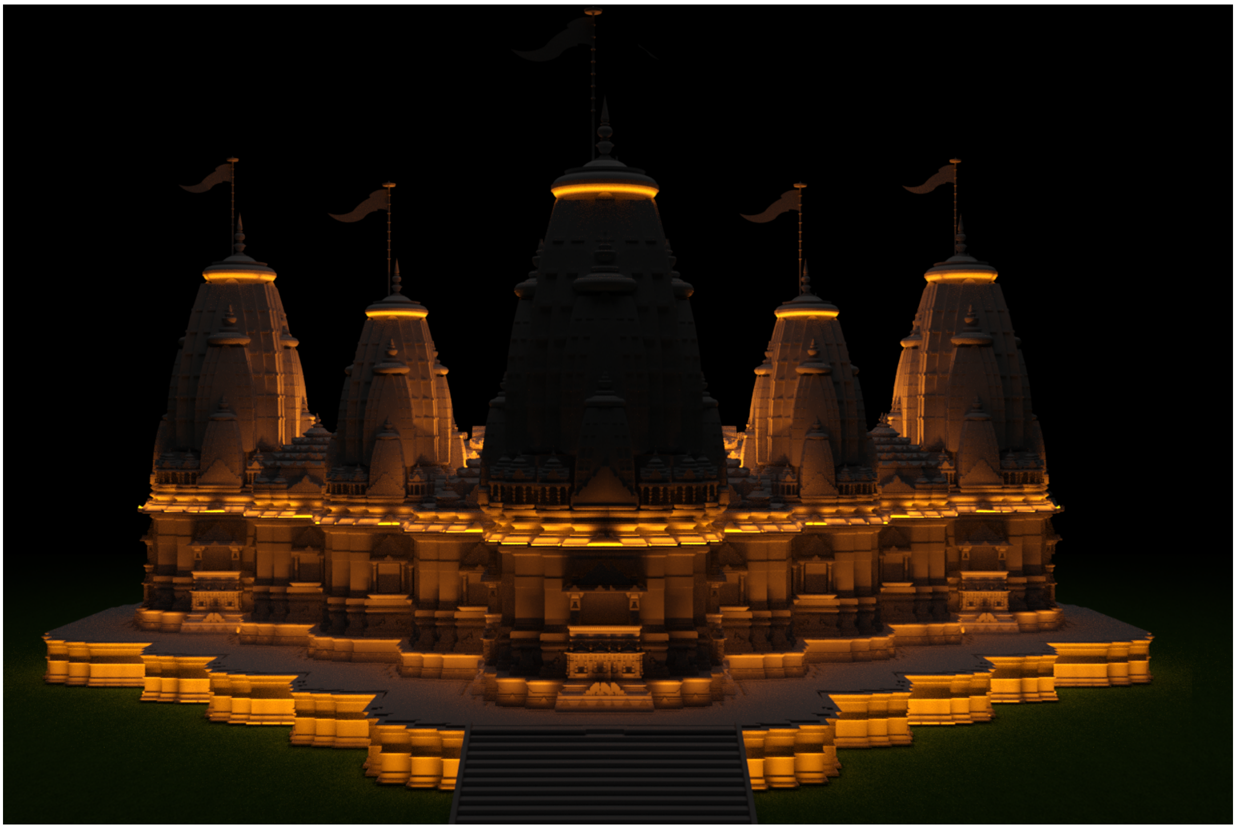


Figure 43: Above image is a screenshot taken in the 3DS Max Software after Rendering (This is the front side of the temple)

This image represents the pilers of the temple (from the front). For illuminating this I have used a flexible IP strip of 2200K CCT for giving the lighting effect. These flexible strips are side bendable with the top illuminating surface, which helps to illuminate the circular part of the peak of the temple.
For controlling these lights with the DALI controller this set is considered “ Group 4”.

Figure 44: Above image is a screenshot taken in the 3DS Max Software after Rendering (This is the front side of the temple)

This image represents the pilers of the temple (from the front). For illuminating this I have 50W Wash light of 2200K CCT for giving the lighting effect to the main coves. For illuminating the whole temple & to give the ambiance some 50W wash lights are also given from the distance with a CCT of 1800K.
For controlling these lights with the DALI controller this set is considered “ Group 5”.

Figure 45: Above image is a screenshot taken in the 3DS Max Software after Rendering (This is the right side of the temple)

This image represents the stairs of the temple (from the right side of the temple). For illuminating this I have used corner profile of 1800K CCT as per the required dimensions for giving the effect of continuous lighting effect. The lights are set up under the staircase with the help of an SS clamp. The L shape of this profile gives the directional output to the staircase which helps to properly illuminate with amber color.
For controlling these lights with the DALI controller this set is considered “ Group 1”.

Figure 46: Above image is a screenshot taken in the 3DS Max Software after Rendering (This is the right side of the temple)

This image represents the pilers of the temple (from the right side of the temple). For illuminating this I have used 1 feet linear wash & 1 meter linear wash of 1800K CCT for giving the lighting effect. The lights are set up with the yoke by screwing the floor. As the lights are set up beside the path of the temple, the beam angle is chosen as asymmetrical to minimize the glare to the visitors and also maintain the light output.
For controlling these lights with the DALI controller this set is considered “ Group 2”.

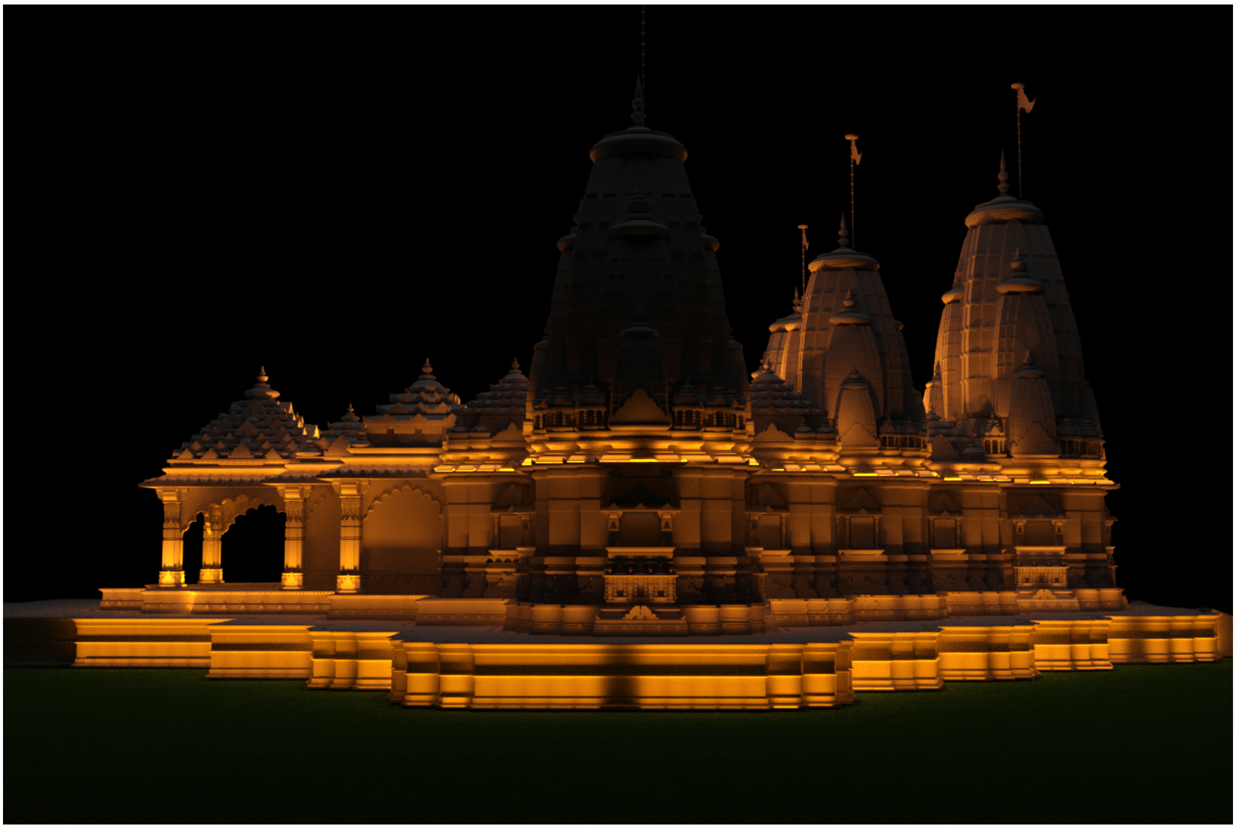


Figure 47: Above image is a screenshot taken in the 3DS Max Software after Rendering (This is the right side of the temple)

This image represents the pilers of the temple (from the right side of the temple). For illuminating this I have used 1 foot linear wash, 2 feet linear wash & 1 meter linear wash of 2200K CCT for giving the lighting effect. The lights are set up with the yoke by screwing the wall. This 2200K CCT gives a more golden vibe to segregate & showcase the craftmanship on the wall of the temple.
For controlling these lights with the DALI controller this set is considered “ Group 3”.

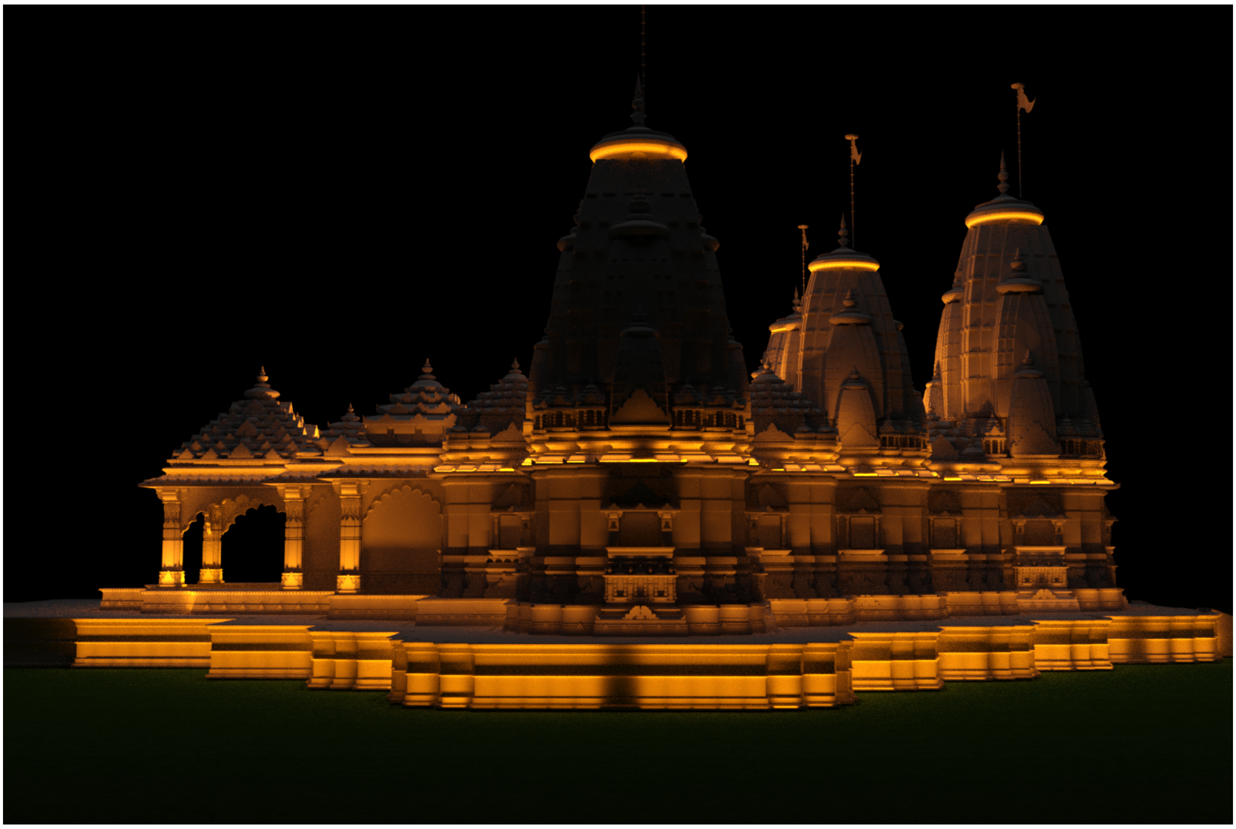


Figure 48: Above image is a screenshot taken in the 3DS Max Software after Rendering (This is the right side of the temple)

This image represents the pilers of the temple (from the right side of the temple). For illuminating this I have 50W Wash light of 2200K CCT for giving the lighting effect to the main coves. For illuminating the whole temple & to give the ambiance some 50W wash lights are also given from the distance with a CCT of 1800K.
For controlling these lights with the DALI controller this set is considered " Group 4".

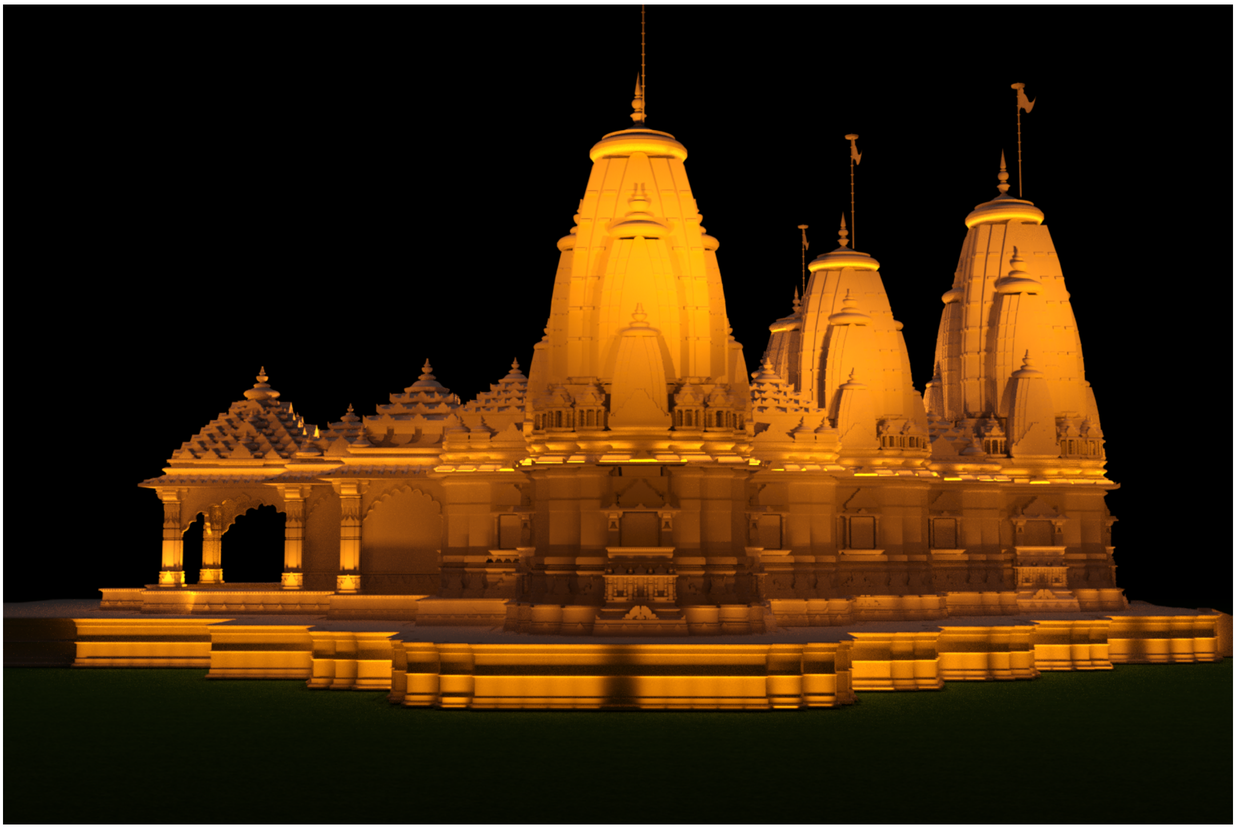


Figure 49: Above image is a screenshot taken in the 3DS Max Software after Rendering (This is the right side of the temple)

This image represents the pilers of the temple (from the right side of the temple). For illuminating this I have 50W Wash light of 2200K CCT for giving the lighting effect to the main coves. For illuminating the whole temple & to give the ambiance some 50W wash lights are also given from the distance with a CCT of 1800K.
For controlling these lights with the DALI controller this set is considered " Group 5".

Figure 50: Above image is a screenshot taken in the 3DS Max Software after Rendering (This is the left side of the temple)

This image represents the stairs of the temple (from the left side of the temple). For illuminating this I have used corner profile of 1800K CCT as per the required dimensions for giving the effect of continuous lighting effect. The lights are set up under the staircase with the help of an SS clamp. The L shape of this profile gives the directional output to the staircase which helps to properly illuminate with amber color.
For controlling these lights with the DALI controller this set is considered “ Group 1”.

Figure 51: Above image is a screenshot taken in the 3DS Max Software after Rendering (This is the left side of the temple)

This image represents the pilers of the temple (from the left side of the temple). For illuminating this I have used 1 feet linear wash & 1 meter linear wash of 1800K CCT for giving the lighting effect. The lights are set up with the yoke by screwing the floor. As the lights are set up beside the path of the temple, the beam angle is chosen as asymmetrical to minimize the glare to the visitors and also maintain the light output.
For controlling these lights with the DALI controller this set is considered " Group 2".

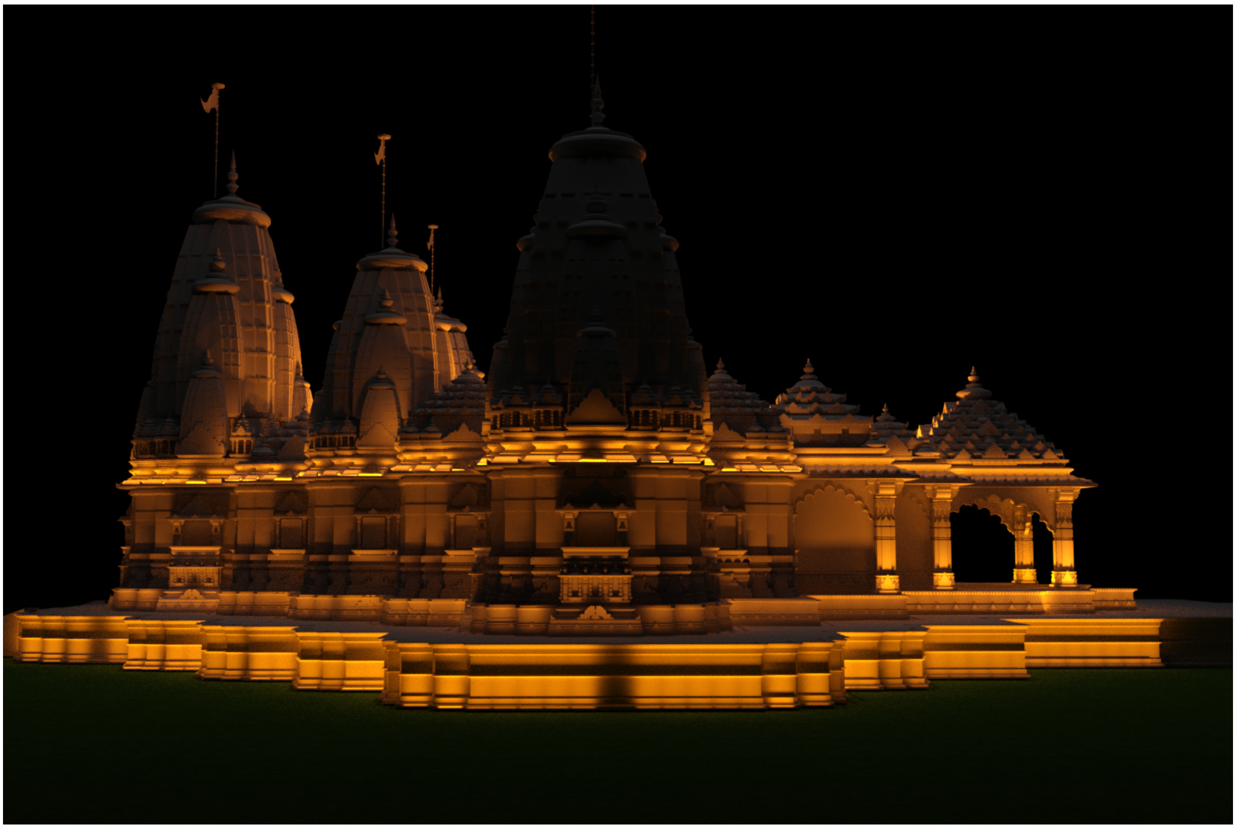


Figure 52: Above image is a screenshot taken in the 3DS Max Software after Rendering (This is the left side of the temple)

This image represents the pilers of the temple (from the left side of the temple). For illuminating this I have used 1 feet linear wash, 2 feet linear wash & 1 meter linear wash of 2200K CCT for giving the lighting effect. The lights are set up with the yoke by screwing the wall. This 2200K CCT gives a more golden vibe to segregate & showcase the craftmanship on the wall of the temple.
For controlling these lights with the DALI controller this set is considered “ Group 3”.

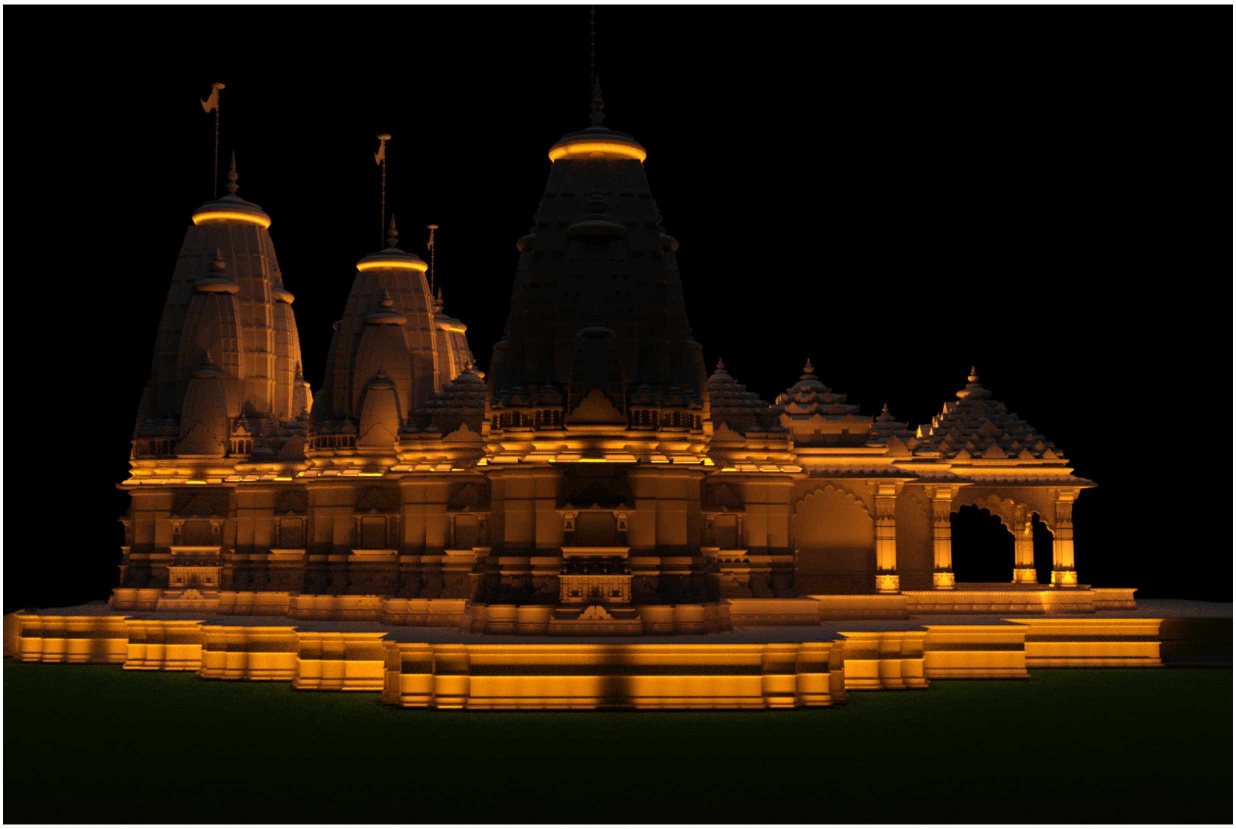


Figure 53: Above image is a screenshot taken in the 3DS Max Software after Rendering (This is the left side of the temple)

This image represents the pilers of the temple (from the left side of the temple). For illuminating this I have 50W Wash light of 2200K CCT for giving the lighting effect to the main coves. For illuminating the whole temple & to give the ambiance some 50W wash lights are also given from the distance with a CCT of 1800K.
For controlling these lights with the DALI controller this set is considered " Group 4".

Figure 54: Above image is a screenshot taken in the 3DS Max Software after Rendering (This is the left side of the temple)

This image represents the pilers of the temple (from the left side of the temple). For illuminating this I have 50W Wash light of 2200K CCT for giving the lighting effect to the main coves. For illuminating the whole temple & to give the ambiance some 50W wash lights are also given from the distance with a CCT of 1800K.
For controlling these lights with the DALI controller this set is considered " Group 5".
The back of the temple & the front of the temple is identical. So the lighting design & control are similar to the front of the temple.
All the grouping control is done by the DALI controller to experience the dynamic illumination of the temple.

4. Conclusion & Future scope

To conclude, as we know lighting plays the most vital & critical role in architectural lighting. It's the role of a lighting designer to design one adequate lighting design which can bring out the craftsmanship of the temple or any architecture. While designing this temple lighting, I've to keep in mind the heights of the walls, pillars, and domes, and accordingly size and wattage selection of the lighting fixtures are done. While placing these lights in the design, I've to keep in mind how the installation can be done in the place, where I'm placing the fixtures in design, because in an architectural lighting execution, installation is a challenging part. All things are reviewed while designing a lighting design to provide a solid foundation for understanding different ways to brighten the illuminating field. The design of a user-responsive dynamic temple lighting is done by DALI control is done in this project. DALI control scheme is used to implement a user-specific time scheduling strategy to save electrical energy as we can dim the brightness of the lights, thus wattage can be reduced and electrical energy can be saved. The full effect of the lights can be done only during the visiting hours of the day.

For future work, we can incorporate a time sensor-based light control scheme and its implementation through other communication technology, viz. RF communication. The applicability of the proposed scheme and its energy-saving potential can be verified through practical implementation in any real-time application.

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