

## *Retraction*

# **Retracted: Performance Analysis and Development of a Semiconductor Junction Rectifier with Multicolor Coding for Indoor Farm Applications**

### **Advances in Materials Science and Engineering**

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This article has been retracted by Hindawi, as publisher, following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of systematic manipulation of the publication and peer-review process. We cannot, therefore, vouch for the reliability or integrity of this article.

Please note that this notice is intended solely to alert readers that the peer-review process of this article has been compromised.

Wiley and Hindawi regret that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

### **References**

- [1] E. D. Kanmani Ruby, M. Umadevi, C. Kanmani Pappa, W. Edwin Santhkumar, P. Janani, and P. Shanmugasundaram, "Performance Analysis and Development of a Semiconductor Junction Rectifier with Multicolor Coding for Indoor Farm Applications," *Advances in Materials Science and Engineering*, vol. 2021, Article ID 6585680, 12 pages, 2021.

## Research Article

# Performance Analysis and Development of a Semiconductor Junction Rectifier with Multicolor Coding for Indoor Farm Applications

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This paper aims to build a smart lighting system with applications such as remote for controlling power supply and optimizing heat management in the metal body of the semiconductor diode and with a printed circuit board for agriculture. The semiconductor diode strips with multiple colors are lined up and configured as a LED lamp with proper casing and heat sink. It has a driver circuit with required power regulation that is able to control the intensity of light for photosynthesis and plant growth requirements. The system uses hydroponics to plant the water, thus decreasing the usage of fertilizers. The entire system is controlled remotely using necessary communication interface application.

## 1. Introduction

The most important mutable factor with respect to plant growth and development is light. The lights in green house application are advantages for plant growth research. The purpose for using grow lights differs and includes increasing light levels for plant photosynthesis or altering the photoperiod [1]. The photoperiod is defined as the period of light a plant perceives. The different lighting sources that growers can use include incandescent (INC) lamps, tungsten-halogen lamps, fluorescent lamps, and high-intensity discharge (HID) lamps. Light-emitting diodes (LEDs) are fourth-generation lighting sources and are an emerging technology in horticulture.

Lead-wire, surface-mounted, and high-power LEDs are three main structural types. LEDs are solid-state semiconductors and when turned on or off, the action is instant and is about 70 percent from initial installation which can

operate up to 50,000 hours. It is not necessary to replace single diodes or lamps constantly because LEDs do not burn out. Factors such as design, materials used, and heat release affect life expectancy. As for consumption of energy, LEDs are more efficient and use less energy than any other traditional greenhouse lights [2]. In addition, operating costs and carbon emissions are lowered when using LEDs.

## 2. Related Works

The authors in [1] have devised a new digital control strategy that is presented for a bridgeless single-stage multioutput AC/DC converter previously proposed as an semiconductor diode grow light. The proposed control system can regulate the output current flowing through each individual diode string, perform power factor correction at the AC side, and provide zero-voltage switching characteristics for all power semiconductors, and the new method reduces conduction

losses associated with transformer windings and power semiconductors by adaptively varying the DC bus voltage; thus, the new control system can result in superior transient response.

The relationship between LEDs and plant growth with respect to a small hydroponic plant is described in [3]. The global population growth and the ongoing climate crisis pose immense risk to the stable food supplies in the future. So, it is necessary to develop a small hydroponic plant cultivation system to ensure supply of nutrients even in extreme circumstances. To build a sustainable system, they have utilized an LED lighting system together with conserved energy generated by sunlight. Such hydroponic plant cultivation systems have to operate at an affordable yet efficient principle.

The authors in [4] specified how we can use Internet of Things (IoT) and build smart garden systems. Internet of Things (IoT) consists of devices that connect to the Internet and communicate with each other. It enables these devices to collect and exchange data with a consumer. This paper presents an IoT-based Smart Garden with Weather Station system, which can be used to monitor the growth of plants every day and predict the probability for raining. Many people interested in growing plants always forget to water the plants. Hence, in this study, the device is equipped with a water pump, where it can be monitored and controlled by using a smartphone. In addition, the device also consists of four main sensors, which are a barometric pressure sensor, a DHT11 temperature and humidity sensor, a soil moisture sensor, and a light intensity module sensor. The soil and light intensity sensor is used to measure the value in percentages. Besides, two actuators, which are the water pump and LED light, can be used remotely or by using a button on the device. The LED is purposely used to replicate the sunlight and make the plant grow faster. This IoT-based Smart Garden with Weather Station System can record the data and send the result to the user through the smartphone application named "Blynk apps." This research is beneficial, and the system can be easily managed by all users such as researchers, farmers, and children.

The way the light supplementation can increase the crop yield in greenhouses by promoting photosynthesis and plant growth has been explained by the authors in [5]. However, the high energy costs associated with light supplementation are a predominant factor that limits development and profit improvement of controlled environment agriculture.

In [6], the authors studied an effective way of light usage for plant growth. The light types included LED, grow light, and natural light. Investigated periods are germination and growth. A plant nursery of  $1.2 \times 1.2 \times 1.5$  m in dimension was used. The structure was made up of PVC tubes. It was covered by black canvas. The system was controlled by a micro-controller. The sensor module DHT22 detected both temperature and humidity. The plant nursery was separated into two rooms for LED and grow light testing. Cooling pads and water dispenser were used for the cooling system. A fan was installed for flowing air. The plant was watered automatically. From the experimental results, it was observed that the plant under LED light had the fastest rate of germination.

In [7], the current agriculture and its advancement are explained, with sustainable food production and security in a demographically obese world, and considered to be the challenging issue. Different technologies were employed to enable farming practices to adapt and build resilience against irregular microclimate shifts. Alternate farming technologies like hydroponic culture technique and integration of smart artificial light and IoT system are deemed promising solutions to the aforementioned problems.

The authors in [8] discussed how to develop a smart LED lighting system [8], which is remotely controlled by Android apps via handheld devices, e.g., smartphones, tablets, and so forth. The status of energy use is reflected by readings displayed on a handheld device, and it is treated as a criterion in the lighting mode design of a system. The wireless data communication is designed to operate in compliance with the ZigBee standard, and signal processing on sensed data is made through a self-adaptive weighted data fusion algorithm. A low variation in data fusion together with a high stability is experimentally demonstrated in this work.

In [9], the authors described how light-emitting diodes (LEDs) have tremendous potential as supplemental or sole-source lighting systems for crop production both on and off earth. Their small size, durability, long-operating lifetime, wavelength specificity, relatively cool emitting surfaces, and linear photon output with electrical input current make these solid-state light sources ideal for use in plant lighting designs.

### 3. Designing of LEDs: Manufacturing Process

*3.1. Frame Precuring for Die Bond.* To begin, it all starts with the precuring of the LED frames [1] in oven 1 for 1 hour at 150 degrees. This is because the metal becomes soft, and it will be easy to do the die bond.

*3.2. Expanding Crystal.* Now, the LED crystals are taken; initially, they are all placed very close to each other, so a compression machine is used to expand the spaces between them. Before that, the LED crystals should be exposed to polarized air for a couple of seconds.

*3.3. Die Bonding.* Die bonding is a manufacturing process used in the packaging of semiconductors, as shown in Figure 1. It is the process of attaching a die (or chip) to a substrate or package by epoxy or solder, also known as die placement or die attach. The process starts with picking a die from a wafer or wafer pack and then placing it at a specific location on the substrate. The die is placed into a previously dispensed epoxy or placed into solder.

The die-attach material plays a key role in the performance and reliability of mid, high, and super high-power LEDs. [10] The selection of the suitable die-attach material for a particular chip structure and application depends on several considerations. These include the packaging process (throughput and yield); performance (thermal dissipation and light output); reliability (lumen maintenance); and cost. Eutectic gold-tin, silver-filled epoxies, solder, silicone, and



FIGURE 1: Die-bonding machine.

sintered materials have all been used for LED die-attach. The use of a particular technology platform often results in trade-offs between different attributes. Mid- to super high-power LEDs are operated at increasing current and power levels (for lighting and mobile ash applications, among others). This trend has brought to the forefront the need for robust thermal dissipation. If the heat is not managed properly [11], the LED performance can degrade significantly, resulting in loss of radiant flux, increase in forward voltage, wavelength shift, and consequently, reduced lifetime. Figures 1 and 2 show the die-bonding machine and mechanism of die bonding, respectively.

**3.4. Die-Bonded Frame for Curing.** After the die bonding is performed, the frames are again placed in oven 2 at 175 degrees for 2 hours. Thus, the LED gets well settled and becomes rigid in place.

**3.5. Wire Bonding.** Wire bonding [9, 12, 13] is the process of creating electrical interconnections between semiconductors (or other integrated circuits) [14] and silicon chips using bonding wires, which are fine wires made of materials such as gold and aluminum. The sample diagram is represented in Figure 3.

Compared to aluminum wedge bonding, gold ball bonding is significantly faster due to being nondirectional, resulting in its widespread use in plastic packaging [15]. However, gold ball bonding on aluminum bond pads cannot be used in hermetic packages due to the high sealing temperatures used in such packages, as these temperatures greatly accelerate the formation of gold-metal intermetallic, which can result in early life failures. Conversely, gold ball bonding on gold bond pads can be utilized in hermetic packages. Figure 4 shows the process of wire bonding.

Gold-aluminum ball bonding requires the use of heat to enable the bonding process [16]. Good bonding between the aluminum bond pad and the gold ball bond without causing damage to the wire, bond pad, or silicon substrate through solely ultrasonic methods is impossible due to the aluminum bond pad being harder than the gold ball bond. The aluminum bond pads are softened by applying thermal energy to them, which encourages the aluminum and gold atoms to interdiffuse, which forms the gold-aluminum bond [17]. The application of thermal energy also improves the bonding

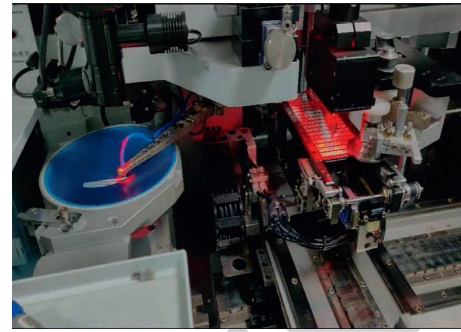


FIGURE 2: Mechanism of die bonding.



FIGURE 3: Wire bonding.

process by eliminating organic contaminants on the surface of the bond pad. Recent transitioning in the wire bonding industry has seen a preference in copper over gold for use in the wire bonding process, with the reason being that the cost of gold is rising. Although there are concerns that copper is less reliable due to its hardness and susceptibility to corrosion, copper wire can be used at smaller diameters, making it more cost-effective.

**3.6. Wire-Bonded Curing.** After the wire-bonding process is complete, the frames are once again placed in oven 1 for pre-curing for half an hour before they go to the dispenser. This in turn settles the wire-soldered material to remain in its place [18].

**3.7. Planetary Mixture.** Planetary mixers [19] are industrial noncontact mixers for all liquids, pastes, powders, and fillers and any combination of liquids or liquids/solids. This includes engineering compounds, pharmaceutical or cosmetic formulations, and nanoparticle dispersions. They mix, disperse, and degas your materials in seconds to minutes, in a sealed or lid-less container such as a jar, beaker, syringe tube, or cartridge [20]. The noncontact mixing principle makes it possible to formulate or combine compounds from very small amounts such as 0.5 ml to large-scale production. By means of both rotation and revolution of the material in a container, materials are mixed and degassed. The materials are placed under an acceleration of 400 G, in which even materials of very high viscosity can be mixed and deaerated or degassed at the same time [21].



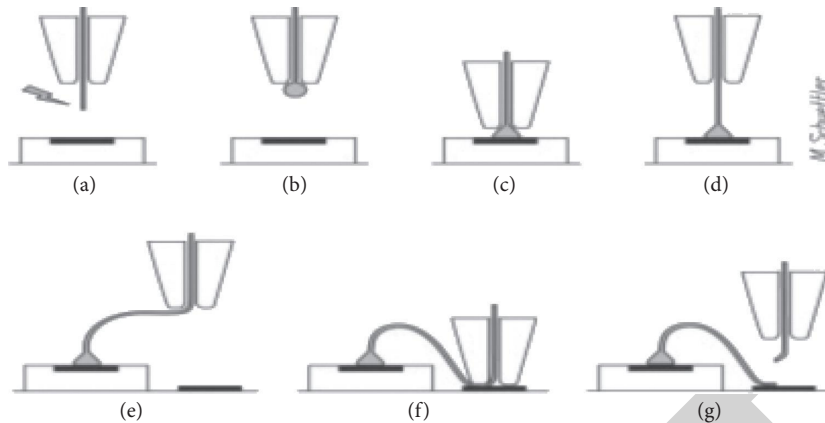


FIGURE 4: Process of wire bonding.

Figure 5 shows the principle in action of two slabs of modelling clay that are completely mixed in a couple of minutes. The stages illustrate the mixing action imparted to the materials by the planetary forces. Lower viscosity materials can mix much faster. All sorts of powders or fillers can be mixed into liquids or pastes in the same way.

**3.8. Dispenser.** The dispensing machine [19, 22] is used to apply high viscous liquids paste material on LED bulbs as well as other round applications. These dispensers are portion-controlled, delivering accurate amounts of the product configured to the preset value, commonly used quantities, or quantities specified by the company. Process selections are made using buttons on the front panel using our unique, state-of-the-art control technology. The dispenser uses a manually operated push switch or cycle start switch to deliver products in a desired quantity. The dispenser consists of a syringe-like device that secretes the required amount of portion onto the LED to give the required wavelength or color [23]. The features of the dispenser include clean dispense, quick cutoff avoiding messy spills, high accuracy and efficiency, increased productivity, continuous and controlled calibrated HMI display, manually and automatically controlled machine, standard high pressure safety valve, and calibrated gauges, designed with ergonomics and aesthetic consideration, reduced labor cost, simplicity of use, and easiness in cleaning.

Different colors can be achieved by the LEDs by using different semiconductors:

- (i) Red: wavelength 625 to 760 nm (AlGaAs)
- (ii) Orange: wavelength 600 to 625 nm (GaAsP)
- (iii) Yellow: wavelength 577 to 600 nm (AlGaInP)
- (iv) Green: wavelength 492 to 577 nm (GaN)
- (v) Blue: wavelength 455 to 492 nm (ZnSe)
- (vi) Violet: wavelength 390 to 455 nm (InGaN)

**3.9. Dispenser Frames Curing.** Once the dispenser completes dispensing the required portions onto all the LEDs, the LEDs are then placed in oven 3 for 1 hour at 100°C and then in oven 4 for 4 hours at 150°C [24].

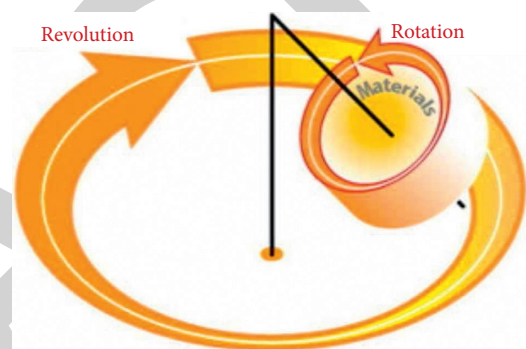


FIGURE 5: Rotation and revolution in a planetary mixture.

**3.10. Frame Tester.** The frame tester is a device that will test the electricity flow in the frame and check whether each and every LED is glowing or not. It will place two metal sticks at the terminals of the LED and give the required voltage to turn it on [25].

**3.11. Single Cutting.** It is a device that will cut the LEDs out of the frame.

**3.12. Bin Sorting.** The device, as shown in Figure 6, will separate all the LEDs according to their wavelength and temperature. A spectrometer is present at the entrance, where every LED will pass through it, and it will detect which wavelength the LED has and will place it in the respective bin; it is the same for the temperature of the LED also. If a LED does not work, it will be placed in a separate bin.

**3.13. LED Precuring for Packaging.** Here, the LED will be heated one last time before being packed.

**3.14. Packaging and Reeling.** Here, the LEDs are placed in a machine that will test them and place them onto a casing that will be reeled automatically. The machine will automatically cut the chain of LEDs when they reach the reel limit [26].

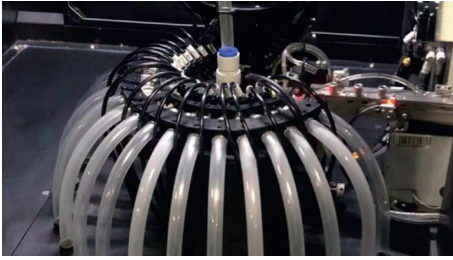


FIGURE 6: Mechanism inside a bin-sorting machine.

3.15. *Packing.* The reels are placed in a cover and then using a vacuum, the air is sucked out and sealed.

#### 4. LED Grow Lights

An LED grow light is an electric light source, which helps plants to grow [1–5]. Grow lights either attempt to provide a light spectrum similar to that of the sun or a spectrum that is more tailored to the needs of the plants being cultivated. Outdoor conditions are mimicked with varying colors, temperatures, and spectral outputs from the grow light, as well as varying the intensity of the lamps. Depending on the type of plants being cultivated, the stage of cultivation, and the photoperiod required by the plants, the specific ranges of spectrum, luminous efficacy, and color temperature are considered to be desirable parameters for some specific plants.

Energy-efficient LED grow lights are the lighting of the future of agriculture [6]. They not only are economic in their use, but produce better plants as well, in comparison to all traditional lighting options.

LEDs outperform incandescent lights in many ways, especially when it comes to energy efficiency. According to Energy Star, the LEDs can save energy at a rate of 90 percent more than incandescent bulbs. The way LED lighting works is when the light source is turned on, it is directional. This means that the LED light aims in a certain direction to provide illumination. But in a compact fluorescent lamp or CFL as well as incandescent bulbs, the light travels in all directions, which decreases energy efficiency due to dispersion of light unnecessarily. Not only do LEDs make a smarter choice for the environment then, but for our wallets as well. Most LED lights will last about 50,000 hours.

4.1. *LED Grow Lights.* These do not solely have to be LED lights. We may also choose to grow your plants with high-intensity discharge lights or HIDs, fluorescents, and incandescent grow lights. No matter which we choose, grow lights generate the right amount of light, so a plant can photosynthesize [27]. This means of conversion gives the plant the energy. Most grow lights are electric, and all are artificial. Plant owners will use grow lights if a plant needs an extra light source besides the sun or if the plant cannot get access to the sun for any reason. For instance, maybe we grow a plant in a cubicle, grow lights, although artificial, try to mimic the sun as naturally as possible. In doing this, we typically have a varying light spectrum available for our grow

lights. Besides the color spectrum, it is also possible to have control over the color temperature and the luminous efficacy with grow lights.

#### 5. Hydroponics

Hydroponics is a method of growing plants indoors without using any soil [3–5, 7]. Instead of pulling mineral nutrients needed for growth from the ground, plants get all of their nutrition through a nutrient solution supplied to their roots. Hydroponics works in a variety of scenarios from growing a small collection of herbs in a kitchen all the way up to numerous plants in a large-scale commercial operation. People with limited or no outdoor space, such as urban residents, apartment dwellers, or renters who cannot have an outdoor garden, find hydroponic growing especially useful [28–33].

The advantages of hydroponics are as follows [8, 9, 34]: firstly, it requires far lesser space than plants grown in soil, and the roots do not have to spread out to search for nutrients and moisture as in hydroponics water, and nutrients are delivered to the roots directly, either intermittently or constantly. Secondly, it conserves a lot of water when compared to soil growing plants. Thirdly, it requires less labor, as it does not require tilling, weeding, and herbicide and insecticide application, as the user is just required to make sure to change water time to time. Fourthly, as it does not require artificial fertilizers, the plants are more natural and organic and have higher quality. Finally, the reason to choose this technology is that the customer using this device can grow his/her own plants or vegetables anywhere they want, and also it is very easy to control it as it is equipped with Wi-Fi and its own app with easy settings. It grows the plants with the highest quality without compromising on the best form of its organic, natural, and nutritious state [35].

5.1. *Selection of Wavelength.* The LEDs selected are 450 nm, 660 nm, 730 nm, and 3000 CCT [9]. The amount of light affects the photosynthesis process in the plant. This process is a photochemical reaction within the chloroplasts of the plant cells, in which CO<sub>2</sub> is converted into carbohydrate under the influence of the light energy. The spectral composition of the different wavelength regions (blue, green, yellow, red, far red, or invisible, e.g., UV or IR) is important for the growth, shape, development, and flowering (photomorphogenesis) of the plant. Figure 7 shows the illumination with various wavelengths. Table 1 shows various wavelengths, vegetative growth, and its effects.

5.2. *Design of the Body.* The body of the design consists of 2 plant holders, a container with partitions for the components, a lid to close the container, and a tube to hold and support the LED profile.

- (i) The dimensions of the container are  $35 \times 20 \times 10$  cm ( $l \times b \times h$ )
- (ii) The dimensions of the plant container are  $30 \times 17 \times 10$  cm ( $l \times b \times h$ )

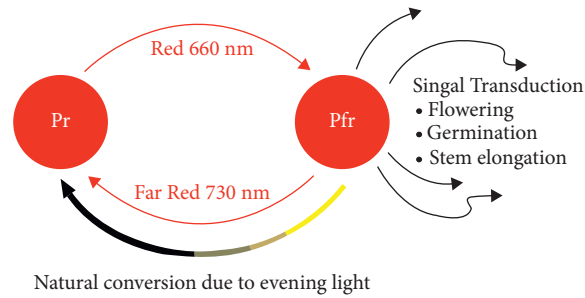


FIGURE 7: Illumination with 660 nm and 730 nm.

TABLE 1: Effects of the particular wavelengths.

Wavelength (nm)	Photosynthesis	Vegetative growth	Effects
450 nm	✓	✓	Leaf expansion, stomatal openings
660 nm	✓	✓	Flowering, budding, stem elongation
730 nm	✓	✓	Germination, leaf building, flowering
3000 CCT white	✓	✓	Boosts the plant growth

- (iii) The dimensions of the holders are  $5 \times 7$  cm ( $r \times h$ )
- (iv) The dimensions of the LED profile are  $30.5 \times 5 \times 3.5$  cm ( $l \times b \times h$ )
- (v) The dimensions of the tube are  $2 \times 35$  cm ( $r \times h$ )

The material used for the body is aluminum, and the body of the device will be welded.

**5.3. Component Selection: Node MCU.** Node MCU is an open-source Lua-based firmware and development board [35] specially targeted for IoT-based applications. It includes firmware that runs on the ESP8266 Wi-Fi SoC from Express if it is based on the ESP-12 module. Figures 8 and 9 represent the images of drivers and motor, respectively.

- (i) Microcontroller: Tensilica 32-bit RISC CPU Xtensa LX106
- (ii) Operating voltage: 3.3 V
- (iii) Input voltage: 7–12 V
- (iv) Digital I/O pins (DIO): 16
- (v) Analog input pins (ADC): 1
- (vi) UARTs: 1
- (vii) SPIs: 1
- (viii) I2Cs: 1
- (ix) Flash memory: 4 MB
- (x) SRAM: 64 KB
- (xi) Clock speed: 80 MHz
- (xii) USB-TTL based on CP2102 is included onboard, enabling plug and play
- (xiii) PCB antenna
- (xiv) Small-sized module to fit smartly inside your IoT projects

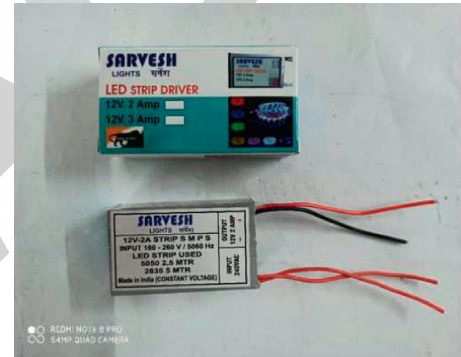


FIGURE 8: 12 V/2 A driver.



FIGURE 9: 1500 rpm motor.

**5.4. Circuit Design.** The LED positive is connected to the power supply positive. The LED negative is connected to the drain of the MOSFET1. The MOSFET1 gate is connected to the microcontroller, and the source is connected to the power supply negative and ground of the microcontroller. The motor positive is connected to the power supply positive. The motor negative is connected to the drain of the MOSFET2 [33]. The MOSFET2 gate is connected to the microcontroller, and the source is connected to the power supply negative and ground of the microcontroller. The 230/

12 V adapter positive wire is connected to a terminal pin in the PCB. The 12 V pin is connected to 3 separate pins on the board. The 3 pins are connected to the positive wire; one of them is connected to the positive terminal of the  $10\ \mu\text{F}$  capacitor that is in turn connected to the input pin of the LM7805 MOSFET. Figure 10 shows the circuit design of MOSFET [34].

The output pin of the LM7805 MOSFET is connected to the positive pin of the  $1\ \mu\text{F}$  capacitor. The negative of the  $10\ \mu\text{F}$  and  $1\ \mu\text{F}$  capacitor, ground of the LM7805 MOSFET, are commonly connected to node MCU 5 V is obtained at the positive pin of the  $1\ \mu\text{F}$  capacitor. This is connected to the Vin pin on the node MCU to power it up. The other pins are connected to the 12 V positive wire; one is connected to the LED strip positive wire, and the other pin is connected to the motor positive wire. A total of 4 LED strips are used; all the positive wires are joined together and given a voltage of 12 V; it is the same for the motor also, as the motor is 12 V and 1500 rpm. Now, the negatives of the LED strips and motor each are connected to each 2N7000 MOSFET's drain pin, and the gate is connected to each PWM pin on the node MCU; here, the pins are D1, D2, D3, and D4. The overall block diagram is represented in Figure 11.

- (i) The 2N7000 MOSFET's source is all commonly connected to the ground on the node MCU

5.5. *LED Strip Design.* 4 LED strip designs are used. The LEDs used in this project are as follows:

- (1) 6–450 nm LEDs (blue), 10 cm
- (2) 6–660 nm LEDs (deep red), 10 cm
- (3) 6–730 nm LEDs (far red), 10 cm
- (4) 6–3000 CCT LEDs (warm white), 10 cm

Figure 12 shows the images of the LED strip. The LEDs are placed in a combination of 3S, 2P, that is, 2 sets of 3 LEDs in series, and both sets are connected in parallel. A LED strip is 5 cm and consists of 3 LEDs each, and each LED is 3 V/150 mA. They are placed in series. In series, the voltage adds and the current stays constant; thus, the LED strip is 9 V/150 mA. Each wavelength has 2 LED strips, that is, 6 LEDs, which is 2 strips set in parallel. In parallel, the current adds and the voltage stays constant; thus, each wavelength LED strip is 9 V/300 mA. The input voltage given is 12 V, and as the required voltage is 9 V, a resistor is used to cause a voltage drop. Voltage drop is  $12 - 9 = 3\ \text{V}$ . Current = 300 mA. Resistance =  $V/I = 3\ \text{V}/300\ \text{mA} = 10\ \text{ohms}$ . Thus, a 10-ohm resistor is used.

For a red LED, the specification is 2 V/150 mA. Thus, each strip of 3 LEDs is 6 V/150 mA. The red wavelength strip consists of 6 LEDs that are 2 strips in parallel, so the specification is 6 V/300 mA. The input voltage is 12 V, and the required voltage is 6 V. Voltage drop =  $12 - 6 = 6\ \text{V}$ . Current = 300 mA. Resistance =  $V/I = 6\ \text{V}/300\ \text{mA} = 20\ \text{ohms}$ , and thus a 20-ohm resistor is used.

The profile is made of aluminum, and its dimensions are  $300 \times 50 \times 35\ \text{mm}$ . All these strips are attached to the profile,

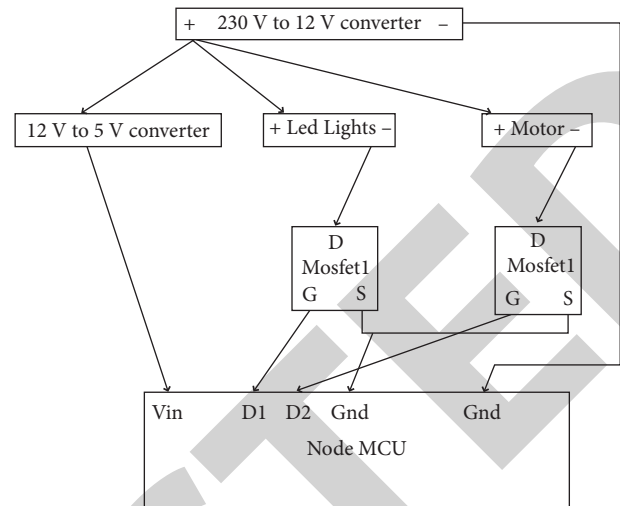


FIGURE 10: Circuit design.

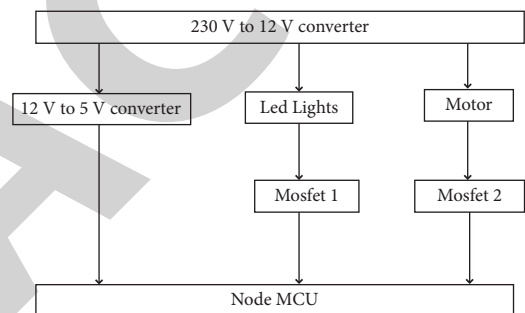


FIGURE 11: Block diagram.



FIGURE 12: LED strip.

which is equipped with a heat sink design. The strips are first glued to the profile using thermal paste and then screwed to them.

5.6. *Outer Body.* The 3D model of the body is shown in Figures 13–15. The outer body of the device consists of 4 parts. The material used is 2 mm aluminum metal sheet. They are (1) plant holder part, (2) electronic component holder part, (3) LED profile, and (4) the goose neck pipe.

5.6.1. *The Plant Holder Part.* The plant holder part consists of 3 plant holders with a diameter of 5 cm. The dimensions are  $300 \times 100 \times 100\ \text{mm}$ .

5.6.2. *The Electronic Component Holder Part.* Its dimensions are  $300 \times 50 \times 100\ \text{mm}$ . Here, the PCB and the motor are placed separately. Front view, side view, and back view of the



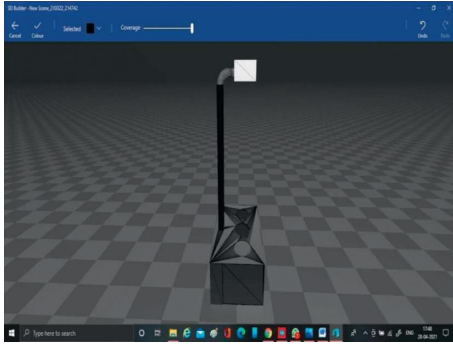


FIGURE 13: Front view of the body.

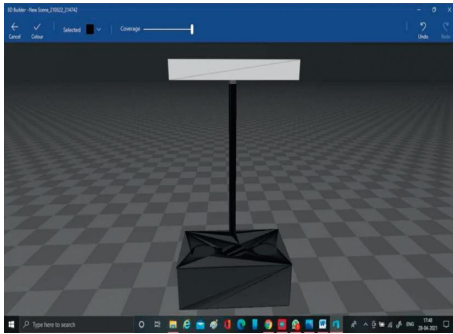


FIGURE 14: Side view of the body.

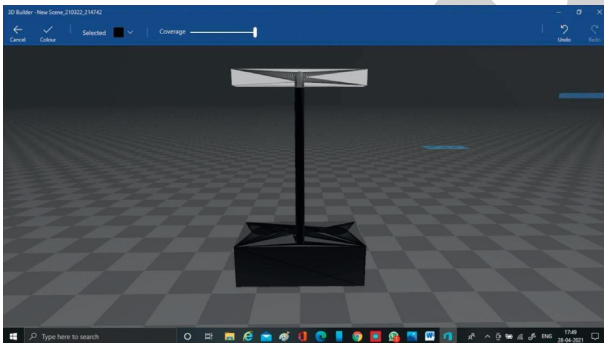


FIGURE 15: Back view of the body.

body are represented in Figures 13–15, respectively. Figures 16 and 17 represent the plant holder part.

Figure 18 depicts the electronic component part, and Figure 19 shows the electronic setup of the entire parts.

**5.6.3. The LED Profile.** The LED profile consists of heat sink on the top. It also has the LEDs stuck to them with thermal paste and screws as shown in Figure 20. Its dimensions are  $300 \times 50 \times 35$  mm.

**5.6.4. The Goose Neck Pipe.** It is a 450 mm long flexible metal pipe with a diameter of 14 mm. It will connect the LED profile to the lower body of the device. Figure 21 shows the goose neck pipe model.

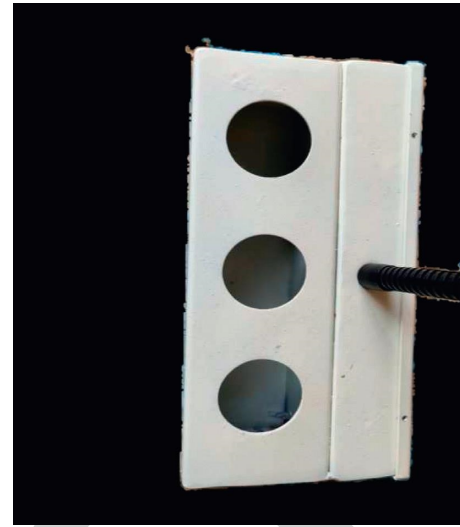


FIGURE 16: Plant holder part.

**5.7. Printed Circuit Board.** Its dimensions are  $60 \times 40 \times 2$  mm. It consists of the respective components: LM7805,  $0.1\text{--}1\ \mu\text{F}$  capacitor,  $1\text{--}10\ \mu\text{F}$  capacitor, 4-2N7000 MOSFET, and 1-node MCU (ESP8266). The LM7805 and the 2 capacitors make the 12 V to 5 V converter, which is represented in Figure 22.

Figures 23 and 24 represent the schematic circuit diagram and PCB diagram, respectively. The 230/12 V adapter positive wire is connected to a terminal pin in the PCB. The 12 V pin is connected to 3 separate pins on the board. The 3 pins are connected to the positive wire; one of them is connected to the positive terminal of the  $10\ \mu\text{F}$  capacitor that is in turn connected to the input pin of the LM7805 MOSFET. The output pin of the LM7805 MOSFET is connected to the positive pin of the  $1\ \mu\text{F}$  capacitor. The negative wire connected to the negative terminal of the  $10\ \mu\text{F}$  capacitor, the ground of the LM7805 MOSFET, and the negative of the  $1\ \mu\text{F}$  capacitor are all commonly connected to the ground on the node MCU.

5 V output is obtained at the positive pin of the  $1\ \mu\text{F}$  capacitor. This is connected to the Vin pin on the node MCU to power it up. The other pins are connected to the 12 V positive wire; one is connected to the LED strip positive wire, and the other pin is connected to the motor positive wire.

A total of 4 LED strips are used; all the positive wires are joined together and given a voltage of 12 V; it is the same for the motor also, as the motor is 12 V and 1500 rpm. Now, the negatives of the LED strips and motor each are connected to each 2N7000 MOSFET's drain pin. The 2N7000 MOSFET's gate is connected to each PWM pin on the node MCU; here, the pins are D1, D2, D3, and D4. The 2N7000 MOSFET's source is all commonly connected to the ground on the node MCU.

## 6. Results

This work aims to find a solution for indoor plant growth using LED lights and hydroponics. The LEDs are a highly

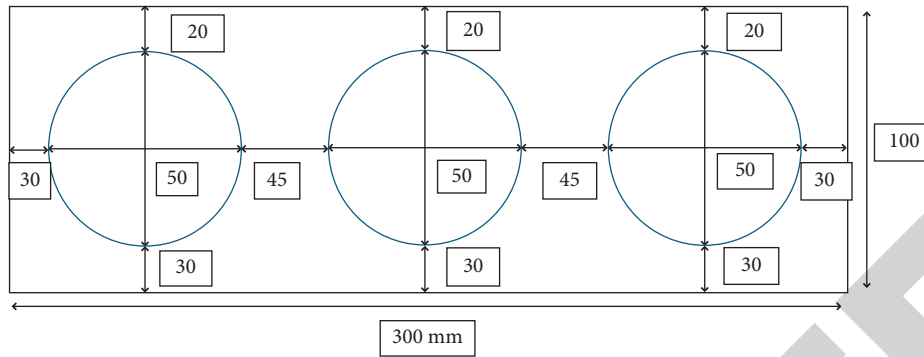


FIGURE 17: Plant holder part.

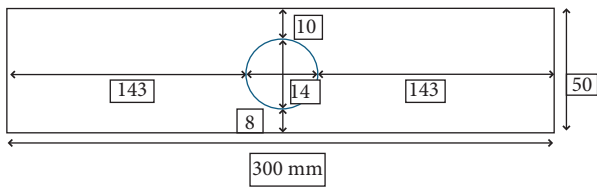


FIGURE 18: Electronic component part.

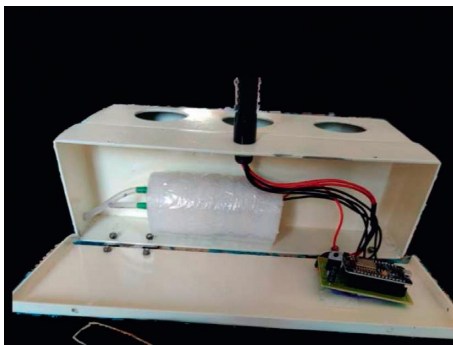


FIGURE 19: Electronic setup.



FIGURE 20: Profile of the LED system.

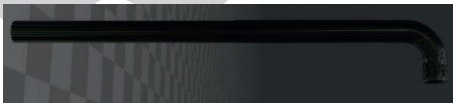


FIGURE 21: Goose neck pipe.

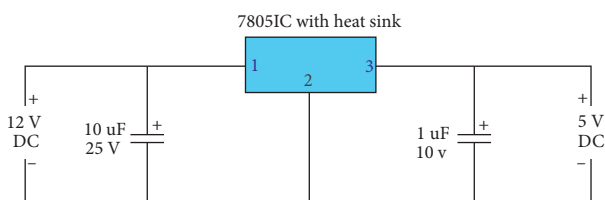


FIGURE 22: 12 V to 5 V converter.

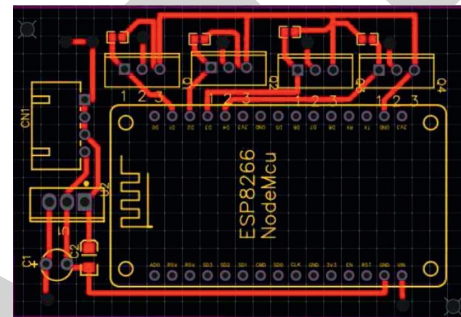


FIGURE 23: Schematic circuit diagram.

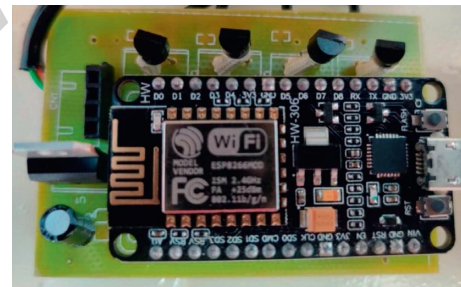


FIGURE 24: PCB.

efficient replacement for sunlight, and hydroponics is good replacement for growing plants without soil. The reason LEDs are used for grow lights is as follows. A 10 W LED bulb produces about 1000 to 1250 lumens, and for the same amount of lumens to be produced by an incandescent bulb, we need a 120 W bulb. Now, the lifetime of a LED bulb is 25,000 hours, and the lifetime of incandescent bulbs is 1200 hours. LED life = 25000 hours and incandescent life = 1200 hours, i.e., 4.8 per cent of 25000 is 1200.

Thus, LED bulb is 95.2 per cent more efficient than incandescent bulb in lifetime. The cost of 10 W LED bulb is around 550 rupees. The cost of 120 W incandescent bulb is around 250 rupees. The cost of LED is 45 per cent more than incandescent bulbs. The yearly power consumption is 1 10 W LED bulb, when it is on 24 hours a day in kWh.

LED bulb:

(i)  $1 \text{ bulb} \times 10 \text{ W} = 10 \text{ W}$  or 0.01 kW

(ii)  $24 \text{ hours daily} \times 365 \text{ days a year} = 8670 \text{ hours}$

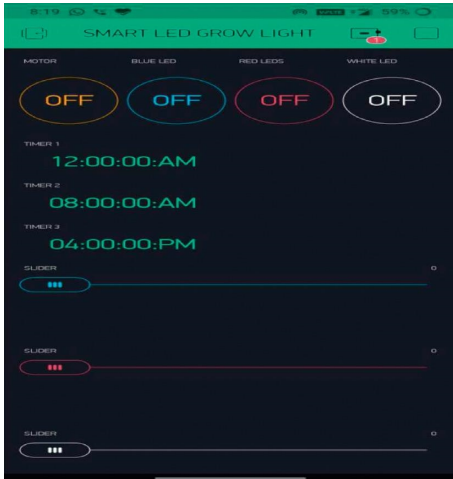


FIGURE 25: Simulation done in Blynk app.

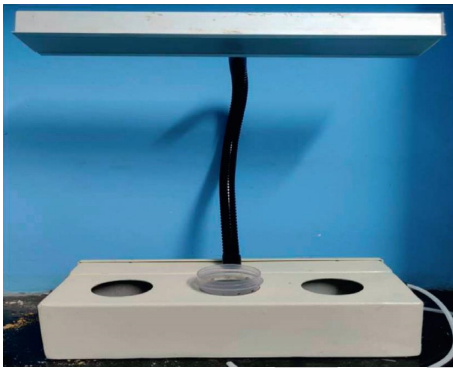


FIGURE 26: The device.

- (iii)  $0.01 \text{ kW} \times 8760 \text{ hours} = 87.6 \text{ kWh}$
- (iv) So, in one year 87.6 kWh is consumed.

Incandescent bulb:

- (i) 7 bulbs are needed to run for 1 year continuously
- (ii)  $7 \text{ bulb} \times 120 \text{ W} = 840 \text{ W}$  or  $0.84 \text{ kW}$
- (iii)  $24 \text{ hours daily} \times 365 \text{ days a year} = 8760 \text{ hours}$
- (iv)  $0.84 \text{ kW} \times 8760 \text{ hours} = 7358.4 \text{ kWh}$
- (v) So, in one year, 7358.4 kWh is consumed. Thus, when compared, the LED bulb is 84 per cent more efficient than the incandescent bulb. This is the solution that is achieved through this project. Figure 25 shows the simulation result of the work.

**6.1. Different Modes of Lightings.** Figure 26 shows the entire device diagram. Figures 27–30 represent the device with various LEDs such as blue, red, white, and all colors LEDs switch ON together. The blue LED with 450 nm lights helps in leaf expansion and stomatal openings, photosynthesis, and leaf expansion. In Figure 28, the red LED lights are turned ON, and if the plant is illuminated with 660 nm, it feels like it is illuminated in the direct sun, and thus, it helps



FIGURE 27: LED system with blue (450 nm) LED ON.

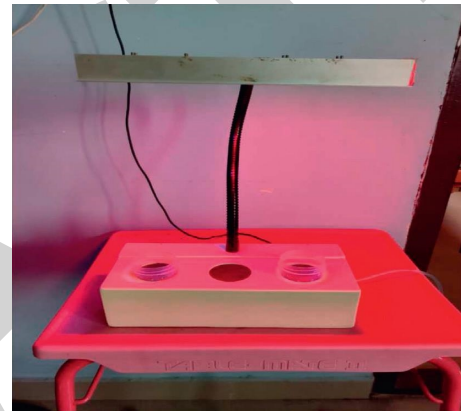


FIGURE 28: LED system with red (660 nm and 730 nm) LED ON.

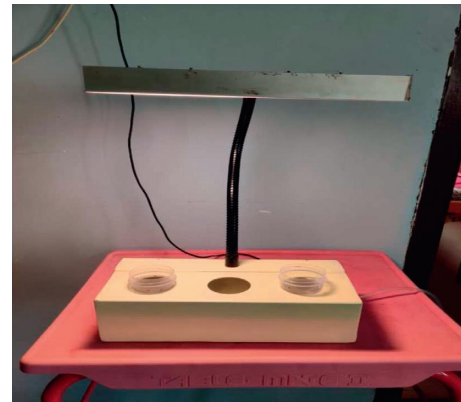


FIGURE 29: LED system with white (3000 CCT) LED ON.

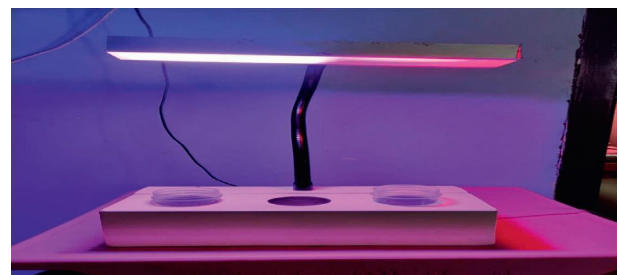


FIGURE 30: LED system with all the LEDs ON.



in stem elongation, and if the plant is illuminated mainly with 730 nm, it feels like it is growing in the shadow of another plant that shades the sun light, thus helping in leaf expansion. In Figure 29, the white LED with 3000 CCT light boosts the photosynthesis and plant growth.

## 7. Conclusion

The goal of this work is to find a solution for indoor plant growth using LED lights and hydroponics that can be used by any plant growing person other than industries. The device comes with 4 modes of lightings and a hydroponics supported body design that enhances the growth of the plants. The LEDs are a highly efficient replacement for sunlight. The wavelengths used in this project are 450 nm blue light, 660 nm deep red light, 730 nm far red light, and 3000 CCT white light. Each wavelength has its own advantages for the growth of the plant. The 450 nm blue light increases chlorophyll production, resulting in healthier foliage, boosts the stem elongation, and increases the stomata openings. The 660 nm deep red and 730 nm far-red light promote growth and flowering; specifically, the 660 nm deep red is very bright and gives plant the feeling that it is growing right under the sun and helps in stem elongation and overall growth of the plant, whereas the 730 nm far red is dim and gives the plant the feeling that it is growing under a shade causing the leaves to expand to absorb more light. It is proved from the analysis that the hydroponic system is good replacement for growing plants without soil. The motor changes the water in the container every 8 hours, which in turn replenishes the plant with fresh water, thus boosting the plant growth and always having abundant water. With this device, any common person who has no prior experience also can use the device to grow their plants without worrying about sunlight or water.

When compared in terms of power consumption of normal grow lights like incandescent to LED grow lights, there is gain up to 80 percentage of efficiency when an LED grow light is used. Even though the LED lights are costlier by 45 percentage than the normal ones, the lifetime of the LED is more by 95 percentage, thus saving the costs by a lot in the long run. That is the solution this proposed methodology aims to achieve.

## Data Availability

The data used to support the findings of this study are included within the article.

## Disclosure

This study was performed as a part of the employment of Mizan Tepi University, Ethiopia.

## Conflicts of Interest

The authors declare that there are no conflicts of interest to publish this article.

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