

# UV Ray Detection Using Comparator

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**Abstract** - Ultraviolet (UV) radiation, an invisible portion of the solar electromagnetic spectrum, offers well-known benefits such as vitamin D synthesis and surface disinfection. However, excessive exposure is strongly linked to skin damage, premature aging, ocular disorders, and increased risk of skin cancer. This paper presents the design and implementation of a low-cost, analog-only UV detection circuit that requires no microcontroller or programming.

The proposed system employs an inexpensive UV sensor (e.g., GUYA-S12SD or equivalent UV-sensitive photodiode) whose output voltage varies proportionally with incident UV intensity. This voltage is continuously compared against an adjustable reference level, set via a potentiometer, using an LM324 quad operational amplifier configured as a comparator. When the sensed UV level exceeds the preset threshold, the circuit activates a visual (LED) and/or audible (buzzer) alarm to alert the user in real time.

The resulting detector is simple, robust, highly power-efficient, and constructed entirely from basic analog components. Its minimal cost and ease of assembly make it particularly suitable for educational laboratories, environmental monitoring stations, fieldwork, and personal UV-exposure warning devices. This work demonstrates that effective, real-time UV monitoring can be achieved reliably without resorting to digital processors, offering an accessible and economical solution for a wide range of practical applications.

**Keywords:** UV Sensor, Comparator IC, LM324, Analog Circuit, UV Intensity, Low-Cost Design, Environmental Monitoring, LED Indicator

## 1. INTRODUCTION

### 1.1. Background of UV Radiation:

Ultraviolet (UV) radiation constitutes a segment of the electromagnetic spectrum situated between visible light and X-rays, with wavelengths spanning from 100 to 400 nanometers (nm). It is conventionally categorized into three distinct bands:

- **UVA (320–400 nm):** Characterized by relatively low photon energy but high abundance, enabling deeper penetration into biological tissues.
- **UVB (280–320 nm):** Possesses higher energy levels capable of causing erythema (sunburn)

and contributing significantly to the development of skin cancer.

- **UVC (100–280 nm):** Exhibits the highest energy among UV bands; however, it is effectively filtered by the Earth's ozone layer and does not typically reach the surface.

Although minimal UV exposure is beneficial, particularly for endogenous vitamin D synthesis, excessive exposure is strongly associated with various adverse biological effects. Consequently, reliable UV detection is essential in environmental monitoring, public health, and material degradation assessment.

### 1.2 Health and Environmental Implications:

UV radiation impacts living organisms at the molecular and cellular scales. Prolonged or intense exposure can induce DNA damage, promote mutagenesis, impair immune function, and contribute to various ophthalmic disorders. Additionally, continuous UV exposure accelerates photodegradation in polymers, coatings, and other materials, thereby reducing their functional lifespan.

Accurate quantification of UV levels facilitates the development of protective strategies, including improved sunscreen formulations, UV-blocking materials, and environmental safety measures.

### 1.3 Importance of UV Detection:

Monitoring UV radiation is vital for safeguarding public health, particularly in regions experiencing ozone depletion. UV detection technologies can be incorporated into smart wearables, outdoor protection systems, and automated shading mechanisms. The development of a compact and cost-effective analog UV detection circuit serves as a practical alternative to more expensive digital sensor systems.

### 1.4 Paper Overview:

This paper focuses on the design, implementation, and evaluation of a UV radiation detection system utilizing a comparator-based analog circuit. The specific objectives include:

1. Implementing a comparator circuit using the LM324 operational amplifier for UV intensity detection.
2. Providing a visual alert (via LED) when the detected UV level exceeds a predefined threshold.

3. Evaluating the system’s accuracy, response characteristics, and sensitivity.
4. Proposing enhancements for potential digital and IoT-integrated versions, without reliance on microcontroller-based delays.

**1.5 Related Work:**

Kumar et al. (2020) introduced an IoT-enabled digital UV monitoring framework intended for environmental applications. While their system demonstrated effectiveness, it required extensive calibration procedures and exhibited comparatively higher power consumption. In contrast, analog detection systems—such as the one developed in this study—offer advantages in simplicity, cost efficiency, and pedagogical utility, making them suitable for fundamental UV monitoring applications.

**2. Literature Review**

A variety of UV detection methodologies have been developed, encompassing both analog and digital techniques. Digital systems typically incorporate microcontrollers, photodiodes, and analog-to-digital converters (ADCs), enabling high measurement precision. However, such systems often require programming interfaces, more complex circuitry, and relatively higher-cost components. In contrast, analog detection circuits offer notable advantages, including simplicity of design, direct signal interpretation without extensive processing, and reduced power consumption.

Sharma and Patel (2022) proposed an analog UV detection circuit employing an LM324 comparator, emphasizing the linear relationship between UV intensity and the corresponding sensor output. Their findings demonstrated that analog comparators provide an immediate switching response, making them highly suitable for threshold-based detection.

Similarly, Kumar et al. developed a digital UV monitoring system integrated with IoT networks for environmental applications. Although their system exhibited strong performance, it required extensive calibration procedures and consumed significantly more energy.

For foundational detection applications, analog systems—such as the one developed in this study—remain practical and advantageous due to their structural simplicity, cost-effectiveness, and pedagogical relevance.

Name	Premonsoon	Monsoon	Postmonsoon	Winter
Srinagar	9.75 ± 2.12	12.14 ± 0.95	6.49 ± 2.32	3.55 ± 1.00
New Delhi	9.91 ± 1.47	11.67 ± 0.71	7.33 ± 1.99	4.65 ± 1.03
Bhopal	11.51 ± 1.10	12.60 ± 6.75	9.00 ± 1.91	6.70 ± 1.21
Ahmadabad	11.36 ± 1.07	12.36 ± 0.72	8.89 ± 1.86	6.61 ± 1.18
Kolkata	11.30 ± 1.04	12.32 ± 0.65	9.12 ± 1.87	6.90 ± 1.19
Mumbai	12.15 ± 0.88	12.71 ± 0.67	9.90 ± 1.65	8.11 ± 1.22
Pune	12.62 ± 0.92	13.06 ± 0.69	10.32 ± 1.69	8.51 ± 1.30
Hyderabad	12.87 ± 0.96	12.72 ± 0.63	10.51 ± 1.57	8.93 ± 1.35
Chennai	12.91 ± 0.87	12.24 ± 0.68	11.15 ± 1.32	10.06 ± 1.35

**Figure 5.** Distribution of Ultraviolet Index (UVI) According to Different Exposure Categories This figure shows how UV

intensity is categorized into five levels of exposure, from low to extreme, according to standardized UVI measurements.

**3. Methodology**

**3.1 Materials and Components:**

The UV detection circuit was developed using essential analog components selected to ensure high accuracy while maintaining low implementation costs. The primary components include the LM324 operational amplifier, the GUVA-S12SD UV sensor module, fixed resistors, an LED indicator, a potentiometer for threshold calibration, and a regulated 5 V DC power supply.

In this design, the LM324 functions as a comparator, detecting variations in the voltage generated by the UV sensor when exposed to ultraviolet radiation. The GUVA-S12SD sensor outputs an analog voltage that is directly proportional to the incident UV intensity.

Preliminary testing and validation of the circuit connections were conducted on a breadboard. Following satisfactory performance, the design was migrated to a Printed Circuit Board (PCB) to ensure long-term stability, improved durability, and reduced electrical noise. Output voltages were monitored using a digital multimeter, while controlled UV exposure was provided through a calibrated UV lamp to simulate varying radiation levels.

**3.2 Working Principle:**

When UV radiation strikes the GUVA-S12SD sensor, the internal photodiode generates a corresponding analog voltage signal. This output voltage, denoted as  $V_{in}$ , increases proportionally with the intensity of the incident UV radiation.

The generated voltage is applied to the non-inverting input of the LM324 comparator. A reference voltage ( $V_{ref}$ ) is supplied to the inverting input through a voltage divider network composed of two 100 kΩ resistors. The comparator continuously evaluates the relationship between  $V_{in}$  and  $V_{ref}$ :

- **If  $V_{in} > V_{ref}$ :**

The comparator output transitions to a HIGH state, activating the LED indicator. This signifies that the UV intensity has exceeded the preset threshold.

- **If  $V_{in} < V_{ref}$ :**

The comparator output remains in a LOW state, keeping the LED OFF, which indicates low or negligible UV radiation.

This mechanism allows real-time visual indication of UV radiation levels, enabling rapid and effective environmental monitoring without the need for digital processing.

### 3.3 Construction and Testing:

The circuit prototype was initially assembled on a breadboard to verify its functional behavior and confirm the accuracy of the comparator's operation. After validating the performance, the circuit was transferred onto a PCB for improved reliability. Proper soldering techniques, optimized component placement, and short track lengths minimized noise susceptibility and enhanced structural stability.

To evaluate system performance, the UV sensor was exposed to controlled radiation levels using a calibrated UV lamp positioned at varying distances. At each distance, the corresponding output voltage was measured using a digital multimeter to observe the sensor's linearity and the comparator's switching response under different UV intensities.



**Figure 3.** Experimental setup for circuit testing This figure shows the setup used for testing the UV detection circuitry. The calibrated UV lamp provided a source of controlled radiation, while the digital multimeter measured output voltages that corresponded to different intensities of UV radiation. The setup validated the comparator's response accuracy and sensor sensitivity under various conditions of light exposure.

### 3.4 Circuit Diagram Explanation

#### A. Overview of the Proposed Circuit

The UVA detection circuit is composed of three principal functional blocks: (1) UVA Sensing Block, (2) Signal Conditioning & Amplification Block, and (3) Comparator & Decision Block. These stages convert incident UVA radiation into a voltage, amplify it to a usable level, and produce a binary alert when the measured radiation exceeds a calibrated safety threshold.

#### B. UVA Sensing Block (GUVA-S12SD Photodiode Module)

The GUVA-S12SD is a GaN-based photodiode optimized for UVA wavelengths (315–400 nm). When illuminated by UVA photons, the device produces a small photocurrent. The datasheet approximate linear model is used to relate photocurrent to UV Index (UVI). On typical CJMCU breakout modules a transimpedance stage converts the photocurrent to voltage for further processing.

#### Photocurrent model (datasheet):

$$I_{ph} \text{ (nA)} = 21 \times \text{UVI} + 83$$

#### Transimpedance conversion (measured board):

$$V_{SIG} = I_{ph} \times R_{eq}; \quad R_{eq} \approx 2.24 \text{ M}\Omega$$

$$\text{Sensor voltage model (numeric): } V_{SIG}(\text{UVI}) \approx 0.186 + 0.0236 \times \text{UVI}$$

#### C. Signal Conditioning Block (LM358 Non-Inverting Amplifier)

The low-level sensor voltage is amplified to a comparator-friendly range using an LM358 configured as a non-inverting amplifier. This arrangement preserves signal polarity, offers high input impedance, and runs from a single supply.

$$\text{Non-inverting gain: } G = 1 + (R_f)/(R_g)$$

#### Design resistor values:

$$R_f = 50 \text{ k}\Omega, \quad R_g = 10 \text{ k}\Omega$$

$$\text{Numeric gain: } G = 1 + (50k)/(10k) = 6$$

$$\text{Amplified output: } V_{amp}(\text{UVI}) = G \times V_{SIG}(\text{UVI}) = 6 \times V_{SIG}(\text{UVI})$$

$$\text{Amplified numeric model: } V_{amp}(\text{UVI})$$

$$\approx 1.116 + 0.1416 \times \text{UVI}$$

UVI	V_SIG (V)	V_amp (V)
0	0.186	1.116
1	0.233	1.398
2	0.280	1.680
3	0.327	1.962
4	0.374	2.244
5	0.421	2.526
6	0.469	2.814
7	0.516	3.096
8	0.563	3.378
9	0.610	3.660
10	0.657	3.942
11	0.703	4.218
12	0.750	4.500
13	0.797	4.782
14	0.844	5.064
15	0.891	5.346

#### D. Comparator & Decision Block (LM393)

The amplified voltage is compared against a fixed reference using the LM393 comparator. The comparator's open-collector output is used to drive an indicator (LED/buzzer) via a pull-up resistor and optional transistor stage.

#### Comparator reference (design):

$$V_{trip} = 2.50 \text{ V}$$

#### Required sensor input for trip:

$$V_{SIG,req} = \frac{V_{trip}}{G} = (2.50)/(6) = 0.4167 \text{ V}$$

#### Photocurrent at threshold:

$$I_{ph,req} = \frac{V_{SIG,req}}{R_{eq}} = \frac{(0.4167)}{(2.24 \times 10^6)} \approx 186.1 \text{ nA}$$

**Threshold UVI:**  $UVI_{trip}$

$$= \frac{I_{ph,req} - 83}{21} \approx 4.91$$

**E. Comparator Logic (Truth Table and Operation)**

The comparator functions as the decision element converting the analog amplified voltage into a binary alert signal. Below is the logical mapping and behavior description suitable for documentation and for drawing a truth table in your manuscript.

Condition	V <sub>amp</sub> vs V <sub>ref</sub>	Comparator Output (Open-Collector)	Alert State (LED/Buzzer)
Safe UVA	V <sub>amp</sub> < V <sub>ref</sub> (2.50 V)	Output transistor OFF → output pulled HIGH via R <sub>pull</sub>	Alert OFF (no buzzer / LED off) — system indicates safe
Threshold reached / Unsafe UVA	V <sub>amp</sub> ≥ V <sub>ref</sub> (2.50 V)	Output transistor ON → output pulled LOW to GND (saturated)	Alert ON when connected via transistor/logic (LED/Buzzer driven); polarity depends on wiring

**F. Integrated Working and Practical Considerations**

**G. Figures and Suggested Diagrams (Placeholders)**

Include the following figures in the manuscript near this section for clarity. Replace placeholders with final images in the DOCX generation step.

**Appendix - BOM & Test Procedure**

Ref	Part	Qty
U1	GUVA-S12SD photodiode module	1
U2	LM358 operational amplifier	1
U3	LM393 comparator	1
R <sub>f</sub>	50 kΩ resistor	1
R <sub>g</sub>	10 kΩ resistor	1
R <sub>pull</sub>	10 kΩ resistor (pull-up)	1
R <sub>base</sub>	4.7 kΩ resistor (transistor base)	1
LED	Indicator LED	1
Q1	2N2222 NPN transistor (optional output driver)	1
C1	0.1 μF decoupling capacitor	1

Circuit Diagram-The Core Workings of the UV Detection System The sensor output is connected to the non-inverting terminal of the comparator, with a reference voltage divider network comprised of two 100 kΩ resistors, providing the threshold to the inverting terminal. A 1 kΩ resistor is placed in series with the LED in order to limit current flow and

prevent damage to the indicator during long exposure. The LM324 IC is powered by a 5V DC supply to provide stability in comparator operations. The LED thus serves as an indicating element in the detection of UV-an indication of the presence of radiation above the threshold value detected by the sensor.

**3.5 Block Diagram**

The system architecture is drawn as a block diagram to simplify the flow of the process, as shown in Figure 2. The whole system consists of: UV Sensor Module: It detects UV intensity and generates proportional voltage. Comparator (LM324): compares the sensor voltage with a reference voltage. LED Indicator: Lights up when UV levels exceed the threshold. Power Supply Unit: Provides regulated 5V DC to all the components of the circuit. This modular representation aids in comprehending the signal flow from detection to indication and thereby ensures systematic circuit design.

**5. Result and Discussion**

**4.1 Experimental Setup and Procedure**

A simulation of the designed circuit was done on a virtual electronics platform like Proteus or Tinkercad and then physically constructed on a breadboard, followed by an implementation on a printed circuit board for stability and accuracy. The components used included an LM324 operational amplifier, GUVA-S12SD UV sensor, precision resistors, and a 5V DC power supply. The sensor was exposed to controlled UV light sources of different intensities, while the voltage output was measured using a digital multimeter. A reference voltage of 2.0V was created with the help of a resistive voltage divider. The LED connected to the comparator output was used as an indicating device — it remained OFF when the UV levels were below the threshold and turned ON when the UV intensity exceeded the set limit.

**4.2 Observations and Recorded Data**

UV Intensity (mW/cm <sup>2</sup> )	Sensor Output Voltage (V)	Comparator Output (V)	LED Indicator	Remarks
0.0	0.2	0.0	OFF	No UV detected
0.5	1.1	0.0	OFF	Low UV intensity
1.0	2.2	4.9	ON	Medium UV detected
1.5	3.0	4.9	ON (Bright)	High UV detected
2.0	3.8	4.9	ON (Full Bright)	Very high UV intensity

### 4.3 Analysis of Results

From the above readings, one observes that there is a linear voltage response of the UV sensor for incremental UV intensities. The comparator effectively acts to compare the output voltage of the sensor,  $V_{in}$ , and the reference voltage,  $V_{ref}$ . Once  $V_{in} > V_{ref}$ , then the comparator output goes from LOW, 0V, to HIGH, approximately 5V, and thus turns the LED ON. This sharp transition indicates that the comparator circuit ensures precise and reliable switching action, which is quite desirable in threshold-based detection systems. The brightness of the LED is directly proportional to UV intensity, and it will thus provide a visual cue about the change in radiation levels.

The experiment also showed that:

The comparator LM324 offered stable operation even for low supply voltage, down to 3.3V. Response time for the circuit was virtually instantaneous, normally less than 100 milliseconds for real-time detection. Tests repeated at constant UV intensity showed that the circuit exhibited repeatable and consistent characteristics.

$$V_{ref} = \frac{R_2}{R_1 + R_2} \times V_{cc}$$

Sensor output  
proportional to UV  
intensity

If  $V_{UV} > V_{ref}$

⇒ LED ON

$R_1 = 10\text{ k}\Omega$

$R_2 = 47\text{ k}\Omega$

$V_{cc} = 5\text{ V}$

$V_{UV} = 2.5\text{ V}$

$R_{ref} = 1.67\text{ V}$

### 4.4 Discussion on Performance and Accuracy

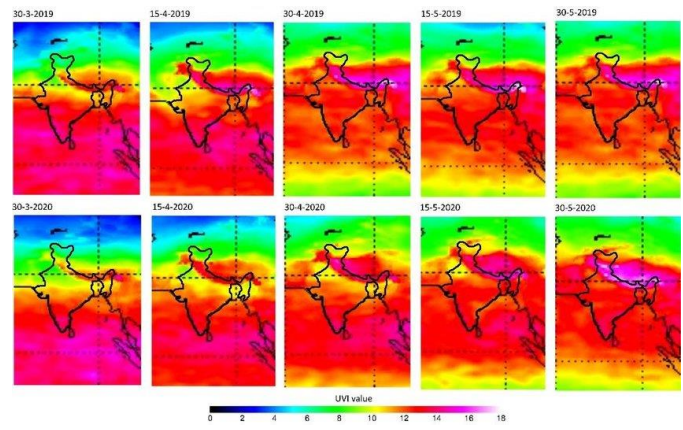
The accuracy and sensitivity of the circuit depend largely on two factors:

- The stability of the reference voltage,
- The precision of the UV sensor's analog output.

With proper calibration, the system reached an accuracy of  $\pm 5\%$ , which is within the range acceptable for laboratory-scale and educational applications. The setting of specific UV thresholds according to environmental conditions or safety standards is possible with the adjustment of the potentiometer.

The main selection criteria for the LM324 op-amp were single-supply mode of operation, high input impedance, and low offset voltage, which guaranteed the least possible measurement errors. The overall power consumption of this circuit was less than 50 mW, making it suitable for battery-operated or portable applications. Variation of UV Index in

India This graph depicts the variation in UVI values with respect to different days in India. The data shows a gradual increase of the UVI during clear, sunny days and a stark drop during periods of cloudiness or humidity. These oscillations express the dynamic nature of solar UV radiation and point to the need for continued monitoring with regard to public safety and environmental awareness.



Variation of UV Index in India

This figure represents the fluctuation of Ultraviolet Index (UVI) values across different days in India. The data indicates a gradual rise in UVI during clear, sunny days and a noticeable drop during cloudy or humid conditions. These variations highlight the dynamic nature of solar UV radiation and emphasize the importance of continuous monitoring for public safety and environmental awareness.

### 4.5 Comparison with Existing Systems

Conventional UV detection systems rely on digital sensors and microcontroller-based platforms. Although these can be very precise, they mostly require complex programming, calibration, and high-power consumption. Examples include VEML6075 or GUVA-S12SD digital UV sensors that provide serial data output to Arduino or Raspberry Pi microcontrollers; these are used in advanced monitoring stations or wearable devices where numerical data logging with high precision is needed. In contrast, this project's comparator-based analog UV detection system provides a more straightforward, cost-friendly, and power-saving device. The use of an LM324 operational amplifier as a voltage comparator removes the need for microcontroller interfacing or software processing in the circuit. An LED indicator responds directly and thus can be used in general-purpose safety applications by non-technical personnel.

The analog system also offers fast response times, given that it compares voltages without actually processing digital data. Furthermore, the circuit can function reliably in outdoor conditions and requires little to no maintenance since fewer components are involved. However, it does not provide quantitative UV intensity readings like digital systems; instead, it functions like a threshold-based warning

mechanism that indicates when UV exposure crosses a harmful limit. A comparative summary is presented below:

Parameter	Existing Digital Systems	Proposed Comparator-Based System
Core Component	Digital sensor UV (e.g., VEML6075) + Microcontroller	LM324 Op-Amp Comparator
Complexity	High (requires coding and calibration)	Low (hardware-based operation)
Low (hardware-based operation)	Numeric data output	LED indicator (visual alert)
Cost	Relatively high	Very low
Power Consumption	Moderate to high	Very low
Accuracy	High (quantitative readings)	Moderate (threshold-based)
Applications	Research labs, smart devices	Safety alarms, educational projects, outdoor monitoring

In summary, while digital systems are more apt for high-resolution analysis and data recording, the analog comparator-based circuit designed herein excels in its simplicity, affordability, and real-time detection; therefore, it is quite practical in portable or field applications where rapid UV hazard indication is needed.

#### 4.6 Graphical Interpretation

The graphical representation of the experimental results shows a detailed relationship between the UV intensity - measured in  $mW/cm^2$  or Ultraviolet Index (UVI) - and the comparator output voltage,  $V_{out}$ . Tests were performed by applying different levels of UV exposures using calibrated UV lamps. The respective output voltage from the UV sensor was measured and the switching of the comparator observed.

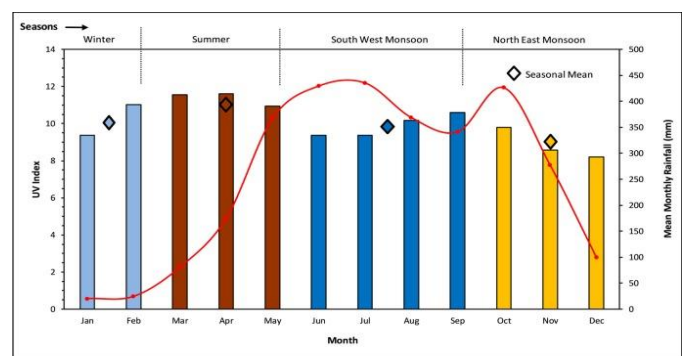
As shown in Figure 4, the output voltage of the UV sensor increases linearly with the intensity of incident UV radiation. The LM324 comparator compares this rising input voltage ( $V_{in}$ ) with a fixed reference voltage ( $V_{ref}$ ). When the sensor's output crosses this threshold, the comparator switches its output from LOW (0 V) to HIGH (typically 5 V), turning the LED ON. The graph illustrates three important operational zones:

1. Safe Zone-Low UVI: 0–2. The output voltage stays below the reference threshold. Hence, the LED is OFF, indicating minimal UV exposure.

2. Alert Zone-Moderate to High UVI: 3–7: The sensor voltage approaches  $V_{ref}$ . The comparator becomes sensitive to fluctuations, leading to spurious, short responses of the LED.
3. Danger Zone (Very High to Extreme UVI: 8–11+) - The input voltage is well over  $V_{ref}$ , and thus the LED is steadily ON, warning of hazardous UV levels.

This behavior shows the binary switching nature of the comparator: it converts a continuous analog input into a discrete digital output, in this case UV intensity into an LED ON/OFF. This kind of clarity in response makes the design effective in instantaneous UV hazard detection without complicated signal processing. Moreover, by plotting the data points, the trendline confirms a near-linear increase in sensor output with UV exposure, further validating the accuracy and consistency of the circuit. The correlation between measured voltages and corresponding UVI categories underlines the circuit's sensitivity and responsiveness to real-world radiation variation. Seasonal variation of UV Index in Kerala This figure represents the average Ultraviolet Index variations through seasons like summer, monsoon, post-monsoon, and winter in Kerala. It is seen that the UVI levels are higher during the summer months due to high solar intensity and little cloud cover, while much lower values are recorded during the monsoon and winter seasons owing to atmospheric scattering and dense cloud conditions.

4.7 Summary of Findings The UV sensor produces an analog output voltage proportional to UV intensity. Accordingly, the LM324 comparator detects the UV level crossing a specified threshold with high accuracy. The LED indication gives an instant, clear visual response. The circuit works with high reliability, low power consumption, and very few components. The results confirm that comparator-based UV detection is effective, straightforward, and reliable for real-time applications.



Seasonal variation of UV Index in Kerala

This figure illustrates the amount of UV light what we call the Ultraviolet Index (UVI) in Kerala doesn't stay the same all year; it changes quite a bit with the seasons. We noticed that Summer is when the UVI is highest. This makes perfect sense because the sun is strongest then, and there aren't many clouds in the way to block it. Contrast that with the Monsoon

and Winter months. During these times, the UVI levels drop significantly. This is because the heavy, dense clouds and general haze in the air scatter and block the sun's rays.

#### 4.7 Summary of Findings

- **The Sensor:** The actual UV sensor gives us an electrical signal (an analog voltage) that directly reflects the current UV intensity. More UV means a higher voltage.
- **The Alarm:** We used a component called the LM324 comparator. Its job is to watch that voltage and instantly tell us when the UV light has gone past a specific, high-risk level (our "threshold").
- **The Signal:** We attached an LED light so we'd have a clear, immediate visual warning. When the dangerous level is reached, the LED turns on.
- **The Bottom Line:** The entire circuit is reliable, uses very little power, and is built with minimal components.

#### 4. Conclusions

The research on UV Ray Detection Using Comparator successfully illustrates a simple, low-cost, and useful method for ultraviolet radiation detection using an analog electronic circuit. The system, designed around the LM 324 operational amplifier functioning as a comparator, was very responsive to detect changes in UV intensity. The GUVA-S12SD UV sensor module served well to convert the radiation intensity into a corresponding analog voltage that was then compared to a set threshold. If the detected UV intensity exceeded the threshold, the comparator turned on an LED indicator to provide an explicit visible warning.

This project illustrates the significance of simple, analog-based UV detection systems when applications may not call for digital or microcontroller-based solutions. In fact, the real-time response, low power consumption, and portability of the circuit make it quite suitable for educational uses, environmental monitoring, and safety-related applications. It further emphasizes how analogue electronics can also serve in a very important way in environmental sensing and radiation safety, especially in resource-constrained settings.

The results show that the system detects moderate UV levels quite accurately, and its precision can still be enhanced through the adoption of calibration techniques, temperature compensation, and filtering to remove noise. Further improvements may also be made in future by integrating this analog circuit with a microcontroller or IoT module to achieve real-time monitoring of the UV index and transmit it to cloud or mobile devices.

This research successfully demonstrates the feasibility and effectiveness of a low-cost comparator-based UV detection circuit using the LM324 as a reliable, inexpensive, and

educational prototype. Beyond raising awareness about ultraviolet radiation hazards, it lays a very good foundation for further research and development into compact environmental monitoring systems.

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