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PROTOTYPE OF CO, CO_2, UV LIGHT, TEMPERATURE, AND HUMIDITY DETECTION DEVICE BASED ON IOT AND SOLAR CELLS

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ABSTRACT: *Exposure to air pollution, excessive ultraviolet (UV) light, and changes in environmental temperature and humidity can have serious impacts on human health. Therefore, a tool design was created that combines Solar Cell-based technology and the Internet of Things (IoT) to detect potential dangers from air pollution, exposure to UV rays, and changes in environmental temperature and humidity. This tool uses an ESP32 microcontroller as its brain, which allows data to be collected from the sensors used. The sensors used include the MQ2 Sensor for toxic gas detection, the MQ135 Sensor for CO2 pollutant gas detection, the UV Sensor for monitoring harmful UV radiation, and the DHT11 Sensor for measuring environmental temperature and humidity. The information collected by these sensors is displayed in real-time via an OLED display, giving users an instant understanding of the level of danger that may exist in their surroundings. Apart from that, this tool uses Solar Cells as a power source, so it can operate independently and is environmentally friendly. This tool has great potential for use in a variety of environments, including residential areas, workspaces, and open areas. It helps society as a whole to maintain their health and safety by providing accurate and real-time information about the dangers that may be around them.*

KEYWORDS: *DHT-11, ESP-32, GUVA S12SD, Internet of Things (IoT), MQ-2, MQ-13, Solar Cell.*

I. INTRODUCTION

Environmental conditions have a significant impact on human and ecosystem health, including air quality, ultraviolet (UV) light exposure, humidity, and temperature changes. Air pollution, particularly from CO2 and CO emissions, is a serious global problem due to vehicular, industrial and fossil fuel combustion activities. Impacts include respiratory distress and irritation. Excess UV exposure can damage the skin and increase the risk of cancer. Extreme temperatures and humidity also contribute to health problems."[1][2][3][4]

Previous research developed IoT-based air quality monitoring tools with a focus on CO and CO2. However, to address this challenge holistically, efficient and porTbl detection tools are needed. The use of renewable energy , such as solar cells, can be an environmentally friendly solution."[5]

In this context, this research designs a hazard detection device that monitors air pollution, UV exposure, humidity, and temperature changes. It provides alerts through buzzers and IoT Remote notifications and telegrams if danger is detected. With its porTbl design and use of solar energy, it enables environmental monitoring in various locations.

The MQ2 and MQ135 sensors detect air pollution, while the UV sensor measures UV exposure. The DHT11 sensor measures temperature and humidity. If any of the sensors detect danger, a buzzer sounds, and the ESP32 alerts the user to seek a safer environment. This approach provides a comprehensive solution for better environmental monitoring.

II. OVERVIEW

A. STANDARDIZATION OF SAFE THRESHOLD VALUES FOR HEALTH

Setting standards for safe threshold values is certainly important in maintaining public health today. The presence of air pollution, UV exposure, temperature fluctuations, and uncontrolled humidity can have a serious impact on human health, therefore, it is necessary to have clear and standardized guidelines to protect the public from health risks arising from these environmental factors."[1][2][3]

In this subchapter, we will discuss in detail the standardization of safe threshold values that have been set by relevant agencies, so that people can take appropriate preventive steps in maintaining their health.

1) Standardization of safe threshold values of CO and CO_2 in air

- Carbon Monoxide (CO) levels in the room.

According to the Minister of Health Regulation No. 2 of 2023 concerning the Implementation Regulation of Government Regulation No. 66 of 2014 concerning Environmental Health, the quality standard for indoor PM 2.5 parameters is 25 micrograms per cubic meter or 0.025 PPM. The threshold set by the World Health Organization (WHO) for PM 2.5 is 15 micrograms per cubic meter or 0.015 PPM.[1]

- Carbon Monoxide (CO) levels in the work environment.

According to Permenaker No.13 of 2012, the threshold value (NAB) of carbon monoxide is 25 ppm, if it is more than the threshold value it can cause health problems in humans [1].

- Carbon dioxide (CO2) levels

Based on the Who Bulletin (2005), the threshold value of CO_2 levels in Indonesia for clean air is 310-330 ppm, while polluted air is 350-700 ppm[1].

2) Standardization of UV exposure threshold values

The World Health Organization (WHO) and the Meteorology, Climatology, and Geophysics Agency (BMKG) use a UV Index scale that generally ranges from 0 to 11+, with high UV index values indicating high levels of UV radiation and greater potential risk. WHO recommends paying attention to the condition of the body when UV rays reach a value of 3 or more. The safe threshold value of UV exposure for health is in the range of 100-400 nm[2].

3) Standardization of humidity threshold value

Health experts recommend an air humidity level (also known as *Relative Humidity (*RH)) in the range of 45% - 75%, as the ideal level.[3]

When the humidity in the room is above 75% (RH), viruses and bacteria that trigger allergies for asthma sufferers will grow rapidly. Conversely, if the humidity is below 45% (RH), the skin, throat, and eyes become dry and itchy, making our bodies more susceptible to disease."[3]

4) Standardization of temperature threshold values

For indoor environments, a comforTbl temperature ranges from 18-25 degrees Celsius. For outdoor temperatures, comfort often depends on personal preference and activity, but temperatures around 20-30 degrees Celsius are considered comforTbl for most people.[3]

B. DEFINITION OF PHOTOVOLTAIC / SOLAR CELL

A Photovoltaic or *solar cell* is a device that functions to convert solar energy into electrical energy. *Photovoltaic* which plays a role in converting solar radiation into electrical energy directly, *Photovoltaic* has components in the form of a collection of solar cells arranged in series or parallel and put together into a solar module[6].

The working principle of solar panels is to illuminate the field of 2 kinds of semiconductor materials with sunlight. Semiconductors play a role in forming an electric field in order to extract electrons and holes with contact materials in order to generate electricity. When P-type and N-type semiconductors are contacted by sunlight radiation (photons), excess electrons in the semiconductor will move from the P-type to the N-type so that the N-type will form a positive pole and the P-type will form a negative pole."[6][7]

C. BATTERY

A battery is an electrochemical cell that can convert chemical energy into electrical energy, where the process it takes place reversibly (can be reversed) with high efficiency. What is meant by reversible electrochemical reactions is the process of converting chemistry into electricity (the process of discharge) and vice versa from electricity converted into chemistry (the process of charging), namely by regenerating the electrodes used, namely by passing an electric current in the direction of the opposite polarity in the cell[8].

D. TP4056

The TP4056 is a constant current/constant voltage linear charger module that functions to charge and discharge batteries. The compact number of components makes the TP4056 suiTbl for porTbl applications. In addition, the TP4056 can work with USB or adapters and is then set for 1A battery charging. There is no diode for blocking on the module, as there is already an internal PMOSFET that prevents the current circuit from charging negatively. The shape of the TP4056 can be seen in Fig 1 below:[9]

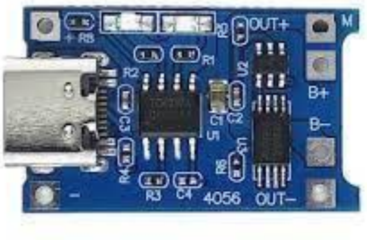

Fig 1. TP4056 Module

E. DC CHOPPER STEP-UP

Chopper Step-Up is a power electronic circuit that functions to convert DC electricity into DC electricity with a voltage greater than the source voltage. To increase the source voltage in the chopper step up circuit, an inductor is given which will store the charge when given the input voltage. The following is a picture of the DC Chopper step up circuit, which can be seen in Fig 2.

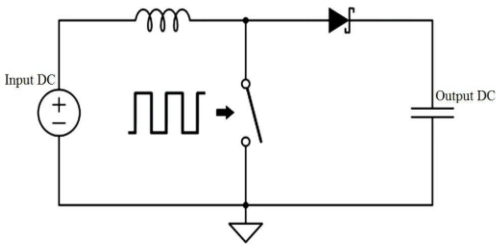

Fig 2. DC Chopper Step-UP circuit

F. ESP32

ESP32 is an SoC (*System on Chips*) microcontroller that is equipped with Wi-Fi accompanied by *Bluetooth* version 4.2 ESP32 is made by an *espressif system* company, ESP32 is designed at a fairly cheap price. In addition, the power required on the ESP32 SoC is quite low, with Wi-Fi facilities & has two Bluetooth models. The ESP32 board has also been equipped with an antenna inside, ESP 32 is usually widely applied to *Internet of Things* (IoT) projects[11].

The presence of this ESP32 module can one day replace the ESP8266 which is well-known in the application of *the Internet of Things* (IoT). Because the CPU in the ESP 32 is faster than the ESP8266, the ESP32 Module has more GPIOs and its most advanced feature is *Bluetooth Low Energy* (BLE)[11].

G. MQ-2 SENSOR

The MQ-2 sensor is one of the gas sensors that functions to detect the presence of gas in the air. This sensor can detect various types of gases that are generally considered potentially dangerous to the environment and can be harmful to human health. The types of gas that can be detected by the MQ2 sensor include LPG (*Liquefied Petroleum Gas*), methane (CH4), carbon monoxide (CO), alcohol, hydrogen (H2), and smoke[12].

H. MQ-135 SENSOR

Like the MQ-2 sensor, the MQ-135 sensor is also one of the gas sensors that function to detect, measure, and monitor several types of gases in the air, such as ammonia, alcohol, benzene, smoke, and carbon dioxide (CO2). The way the MQ-135 sensor works is by detecting the level of presence of potentially dangerous gases in the vicinity, which then becomes an analog signal that will then be forwarded to the microcontroller input to the system [13].

I. UV SENSOR

The GUVA-S12SD sensor is an *ultraviolet* (UV) sensor that functions to detect and measure the intensity of *ultraviolet* light commonly used in projects that require monitoring of *ultraviolet* radiation in the environment. The following is an image of the physical form of the GUVA S12SD sensor which can be seen in Fig 3:[14]

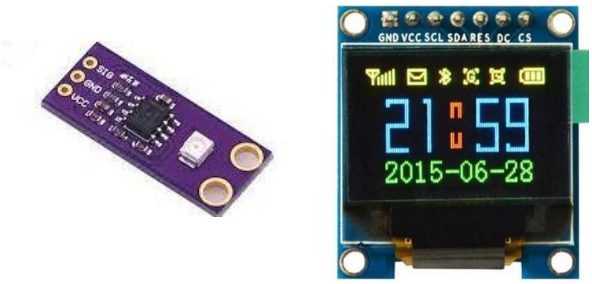

Fig 3. GUVA S12SD Sensor

J. DHT-11 SENSOR

The DHT 11 sensor is a sensor that functions to measure temperature and humidity objects that have analog voltage outputs which can then be further processed with a microcontroller to create the required project. The DHT11 sensor belongs to a resistive element such as a temperature measuring device, namely NTC. The advantage of the DHT-11 sensor with other sensors is in terms of the quality of reading more responsive measurement data which has speed when measuring temperature and humidity. [15]

K. BUZZER

A buzzer is an electronic component that functions as a converter of electrical vibrations into sound vibrations. The working principle of the *buzzer is* almost similar to the *Loudspeaker*, so in the *buzzer*, there is also a coil attached to the diaphragm the coil will be electrified so that it becomes an *electromagnet*, the coil will be pulled in and out, depending on the direction of the current and the polarity of the magnet, When the magnet is attached to the diaphragm, any coil movement that occurs will move the diaphragm back and forth which will make the air vibrate and then produce sound. *Buzzer* in its application is usually used as an indicator when the program has been completed or there is a problem with the tool (alarm) [16].

L. OLED Screen

OLED display stands for *Organic Light Emitting Diode*. As the name suggests, OLEDs are formed from organic materials to emit light when in contact with electricity.

The advantage of OLED displays is that they are energy efficient because the backlight is not powered so the black color displayed is also completely black, this is because the pixels are completely dead.
The disadvantage of OLED displays is that because they are formed from organic materials, OLEDs will experience color degradation over time. Of course, this will affect both in terms of brightness and color balance. The following is the shape of the OLED screen which can be seen in Fig 4 below: [17]

Fig 4. OLED display

M. Arduino IDE

Arduino IDE which stands for *Integrated Development* Environment, is commonly used to create commands and *source code*, perform error checking, and compilation, upload programs, and can test the results of Arduino work that can be seen through a serial monitor. The program file created in the Arduino IDE is usually called a "*sketch*" with the .ino file format [18].

N. Internet of Things (IoT)

Internet of Things is the concept of an object or object that is embedded with a technology such as sensors and software that aims to communicate, control, monitor, or exchange data through other supporting devices as long as it is still connected to the *Internet of Things* can interconnect between users and objects in unlimited time or place. The *Internet of Things is* designed so that the system can be self-conFigd and can adapt both from sensor networks and smart objects that aim to connect all things, including objects in the industrial realm, IoT is also designed in such a way as to make it intelligent, programmable and able to interact with humans. [19]

O. How the whole tool works

The workings of this tool system, which is set up in such a way as to monitor several environmental parameters through sensors, including MQ-2, MQ-135, UV, and DHT11, which periodically send data to the ESP32. The ESP32 serves as the data processing center, displaying the measured information on an OLED screen. If the data obtained from the sensors exceeds a certain threshold, the ESP32 automatically activates an alert mechanism. For example, the MQ-2 sensor sends an alert if the carbon monoxide (CO) gas level exceeds 25 ppm, the MQ-135 sensor gives an alert if the carbon dioxide (CO2) level exceeds 310 ppm, the UV sensor alerts on UV radiation above 310 UV, and the DHT11 sensor gives an alert if the temperature exceeds 35 degrees Celsius or the humidity is above 85%.

When these limits are exceeded, the ESP32 will send alerts to monitoring platforms, such as Telegram and Arduino IoT, notifying users of conditions that exceed the set limits. In addition, to
provide visual or audible alerts locally, a buzzer will sound as a sign of danger. With this integration, the system not only provides real-time monitoring but also provides rapid response to significant changes in environmental conditions. The range of tools can be seen in Fig 5.

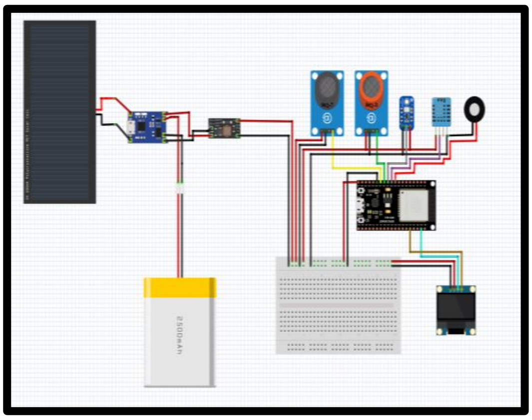

Fig 5. Tool Set

P. Tool Shape Design

The design of the tool shape in this study is very important, taking into account several factors in order to achieve the research objectives. This tool is designed to detect hazards that can be used in various places, so in this study, the design is made by paying attention to materials and sizes, so that this tool can make it easier when operated in various places. The shape of the tool can be seen in Fig 6 below:

Fig 6. Tool Shape

III. METHODOLOGY

The method used in making this design is the *HardwaremProgramming* Method. This method goes through several stages of making, namely:

1) *Conceptual Design*
   - Identification of needs: Analyze the needs to formulate tool design specifications.
   - Tool concept: Initial concept design based on needs analysis by considering ergonomic and functional factors.
2) *Detail Design*
   - Design plan development: preparation of a design plan that includes details of materials, components, and tool dimensions.
   - 3D Design: Implementation of detailed design into 3D using CAD (Computer-Aided Design) software.
3) *Prototype Assembly*
   - Component assembly: Assemble all components of the device following the design, and with attention to the necessary connections and adjustments.
   - Initial testing: Perform initial testing to ensure each component can function properly and follow expectations.
4) *Functional Testing*
   - Performance testing: Evaluate the performance of the tool using test scenarios in real use.
   - Accuracy measurement: measuring the accuracy of the tool by comparing the standard tool in the field.
5) *Documentation*
   - Report writing: compile a research report that includes the entire tool development process, test results, and conclusions drawn.

This research method describes the steps taken from the conceptual design stage to documentation to ensure the successful development of a prototype tool in the context of the research.

IV. RESULTS AND DISCUSSION

A. SOLAR CELL TESTING AND ANALYSIS

Sollar cell testing is carried out to determine the voltage and current generated to charge the battery, voltage and current measurements are carried out in 10 measurements with different sunlight intensities. To calculate the power of the solar cell use equation 1 below:

P= VxI (1)

P = Power V = Voltage I = Current

Example:

P = (5870 mV) x (150.9 mA) = 885.78 mW

The results of the measurements can be seen in Tbl 1 below:

Tbl 1. Solar cell test results

Test	Measurement Results			
	Hours (WIB)	Teg Output (VDC)	Output Current (mA)	Power Output (mW)
1	9.00	5,87	150,9	885,78
2	9.30	5,92	153,2	906,94
3	10.00	6,02	156,9	944,53
4	10.30	6,06	158,5	960,51
5	11.00	6,09	160,3	976,22
6	11.30	6,12	162,8	996,33
7	12.00	6,12	162,8	993,08
8	12.30	6,10	161,3	983,93
9	13.00	6,09	160,4	976,83
10	13.30	6,08	159,3	950,30

Measurements were taken on January 17, 2024, with different solar intensities located in the Pakuan University campus environment, using a multimeter connected directly to the solar cell.

Analysis Tbl 1 above shows the results of measuring the output voltage (VDC) on the solar cell obtained an average voltage of 6.04 Volts DC. and a current of 158.51 mA While the resulting power obtained an average value of 957.44 mW. So that the *solar cell* can operate to charge the battery properly due to the battery voltage rating (3.7 volts) and the TP4056 module (4.5 volts).

B. BATTERY TESTING AND ANALYSIS

Measurement and Testing on the Battery is done by charging the battery using a 5V 3A *power supply* and a 5V 1A TP4056 module. The battery used in the test is a lithium polymer battery.

Here are the results of the battery calculation. To find out the time required for one full charge/discharge of the battery can be calculated by equation 2 as follows:

Charging/discharging duration = $\frac{\text{battery capacity (Ah)}}{\text{Charging/discharging current}}$ (2)

a. Using 5V 3A *power supply*

Charging duration (h) $= \frac{2{,}5\ Ah}{3\ A}$

= 0.83 h (50 minutes)

b. Using the TP4056 module

Charging duration (h) $= \frac{2{,}5\ Ah}{1\ A}$

= 2.5 h (150 minutes)

c. Battery usage time

Discharging time (h)= $\frac{2{,}5\ Ah}{0{,}5\ A}$ = 5 h (300 minutes)

Based on the results of the above calculations, it can be seen that using the average charging current obtained of 1A and 3A, the charging time takes approximately 50-150 minutes, and the battery supplies the tool for approximately 5 hours (300 minutes).

C. MQ-2 Sensor Testing

CO level readings and Sensor Testing
This test was carried out to determine CO levels and accuracy, this test was carried out 7 times.

To get the error value, it can be calculated using equation 3 as follows:

Error Value = $\frac{\text{Reading value} - \text{Comparative value}}{\text{Comparative value}}$x100% (3)

Example: Error Value = $\frac{4-6}{6}$x100% = 0,3%

The following are the results of the test which can be seen in Tbl 2 below:

Tbl 2. MQ-2 sensor test results

No.	At	Sensor Readings (PPM)	Comparator Reading (PPM)	Error Value (%)	Accuracy (%)
1	08.30	4	6	0,3	99,7
2	08.45	4	6	0,3	99,7
3	13.15	7	10	0,3	99,7
4	13.30	9	15	0,4	99,6
5	16.15	6	12	0,5	99,5
6	16.30	10	17	0,4	99,6
7	20.15	1	3	0,6	98,4

Testing was carried out on Thursday, January 25, 2024, which took place in 3 locations, namely Pakuan University classrooms, Danau Bogor Raya and Baranangsiang using a comparison tool (breath), test results can change according to environmental conditions.

From the results of carbon monoxide measurements taken at three different locations, namely the room, Danau Bogor Raya, and Baranangsiang, the lowest Fig was obtained at 1 PPM and the highest Fig of 10 PPM, while the threshold value is at 25 PPM. So that the value of carbon monoxide levels in the three locations is still in a safe condition. And after being compared, the average value of accuracy on the MQ 2 sensor is 99.45%.

D. MQ-135 Sensor Testing

Sensor Accuracy Readings and Testing, This test was carried out to determine the CO levels and accuracy of the sensor, and this test was carried out 7 times.

To get the error value, it can be calculated using equation 3 as follows:

Error Value = $\frac{\text{Reading value} - \text{Comparative value}}{\text{Comparative value}}$x100% (3)

Example: Error Value = $\frac{115-122}{122}$x100% = 0,05%

The following are the results of the test which can be seen in Tbl 3 below:

Tbl 3. MQ-135 sensor test results

No.	At	Pem Sensor readings (PPM)	Pem Pem reading appeal (PPM)	Error Value (%)	Accuracy (%)
1	08.30	115	122	0,05	99,95
2	08.45	110	120	0,08	99,92
3	13.15	27	25	0,08	99,92
4	13.30	110	95	0,15	99,85
5	16.15	90	93	0,03	99,97
6	16.30	88	91	0,03	99,97
7	20.15	15	20	0,25	99,75

Testing was carried out on Thursday, January 25, 2024, which took place in 3 locations, namely Pakuan University classrooms, Danau Bogor Raya and Baranangsiang using a comparison tool (breath), test results can change according to environmental conditions.

From the results of carbon monoxide measurements taken at three different locations, namely the room, Danau Bogor Raya, and Baranangsiang, the lowest Fig was 15 PPM and the highest Fig was 122 PPM, while the threshold value was 310 PPM. So that the value of carbon dioxide levels in the room is in a safe condition, while at the Lake Bogor Raya and Baranangsiang locations, the value of carbon dioxide levels changes according to the density of transportation. After being compared, the average accuracy value of the MQ 135 sensor is 99.88%.

E. UV Sensor Testing

This test is carried out to determine the characteristics of the sensor, and this test is carried out 10 times. The following are the results of the test which can be seen in Tbl 4 below:

Tbl 4. UV sensor test results

No.	Input (nm)	Output (VDC)	With Volt meter (VDC)
1	12	0,06	0,05
2	16	0,07	0,06
3	89	0,44	0,27
4	215	1,08	0,32
5	293	1,47	0,59
6	303	1,52	1,02
7	276	1,38	0,50
8	646	3,23	2,38
9	779	3,90	2,59
10	430	2,15	1,60

The data in Tbl 4 above, shows that the greater the UV value detected, the voltage output from the sensor will also increase.

F. DHT-11 Sensor Testing

This test is carried out to determine accuracy, and this test is carried out 8-10 times.
To get the error value, it can be calculated using equation 3 as follows:

$$\text{Error Value} = \frac{\text{Reading value} - \text{Comparative value}}{\text{Comparative value}} \text{x}100\% \quad (3)$$

$$\text{Example: Error Value} = \frac{115-122}{122}\text{x}100\% = 0{,}05\%$$

The following are the results of the test which can be seen in Tbl 5 and Tbl 6:

Tbl 5. Temperature and humidity test results

No.	DHT-11 Sensor Readings		Thermometer Reading		Accuracy (%)
	°C	%	°C	%	
1	27,10	87,00	27,20	84	99,97
2	27,10	88,00	27,20	84	99,96
3	27,60	88,00	27,65	85	99,97
4	28,00	87,00	28,05	84	99,97
5	28,50	88,00	28,60	86	99,98
6	29,00	84,00	29,30	80	98.65
7	29,30	83,00	29,40	80	99,97
8	29,30	81,00	29,37	79	99,98
9	27,10	87,00	27,15	82	99,94
10	27,10	86,00	27,15	84	99,98

Testing was carried out on Thursday, January 25, 2024, which took place in 3 locations namely Pakuan University classrooms, Danau Bogor Raya, and Baranangsiang using a Thermometer comparison, test results can change according to environmental conditions.

Tbl 6. Sensor voltage test results

No.	DHT-11 Sensor Readings		Volt Meter (VDC)
	°C	%	
1	27,10	87,00	1,02
2	27,60	88,00	1,07
3	28,00	87,00	1,20
4	28,50	88,00	1,20
5	29,00	84,00	1,60
6	29,30	81,00	1,50
7	27,10	87,00	1,07
8	27,10	86,00	1,08

The data Tbl 6 above shows that the greater the temperature and humidity values detected, the voltage output from the sensor will also increase.

V. Conclusion

Based on the measurement data obtained, several conclusions can be drawn regarding the performance of the environmental measurement system using solar cells, ESP32, and various sensors. The solar cell was able to provide an average output voltage of 6.04 Volts DC and an average current of 112.34 mA, demonstrating its ability to effectively charge the battery. The battery charging time is about 2 hours under bright sun conditions, indicating that the solar panel can produce the optimal voltage. The input voltage on the ESP32 has an average value of 5.02 Volts DC, corresponding to the working voltage range of the ESP32 (3-5 Volts DC), indicating adequate power availability. Carbon monoxide (CO) values at the three sites were within the safe range, with the highest value at 10 PPM, below the threshold of 25 PPM. Carbon dioxide (CO2) values at general locations are below the threshold of 122 PPM, but at some specific locations fluctuate according to transportation density. The UV exposure values at the three locations are still safe, ranging from 0 to 110 UV, below the threshold of 300 UV. The temperature and humidity sensors show responsive readings and are fit for purpose, giving different values at different times but still within acceptable ranges.

Thus, the overall system performed well in monitoring and measuring environmental parameters. The solar cell successfully generates enough power for system operation, and the values measured by the sensors are within the safe range. The integration of the ESP32 as the data processing center also successfully performed the measurement and warning functions. Note that fluctuations in the values of some sensors can be attributed to variations in activity and density at the measurement site.

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