Journal of Engineering Research and Reports

Volume 24, Issue 6, Page 35-46, 2023; Article no.JERR.97146
ISSN: 2582-2926

Design and Implementation of a Microcontroller-based Weather Acquisition Device

Aneke Chikezie Samuel [a*], Asuquo Philip Micheal [a] and Ozuomba Simeon [a]

[a] *Department of Computer Engineering, University of Uyo, Akwa Ibom State, Nigeria.*

Authors' contributions

This work was carried out in collaboration among all authors. Authors ACS managed the literature searches and wrote the first draft of the manuscript. Authors APM and OS managed the final compilation of the manuscript. All Authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JERR/2023/v24i6823

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/97146

Original Research Article

Received: 02/02/2023
Accepted: 26/02/2023
Published: 09/03/2023

ABSTRACT

An atmospheric data acquisition device is designed to ease and improve on the current method of acquiring Temperature, Pressure, and Relative Humidity measurement at different altitudes. The proposed work aims to solve the problem of inadequate atmospheric data by monitoring atmospheric weather conditions using sensors while the microcontroller processes the data collected and relays it to the user. This research was carried out at the University of Uyo, between September 2018 and January, 2023. Considering that weather forecasting is of the utmost importance in our current society, the system has been built using a BME280 module for the atmospheric parameters acquisition, an ESP8266 as the microcontroller for Data processing, and a wireless module for processing and transfer of the data from the BME module, a NEO6M GPS module for longitude and latitude, a Li-ion cell to power the components and a TP4056 circuit to recharge the Li-ion cell. A web application Thingspeak.com was incorporated to help the user interact and access the data to enable ease of understanding and real-time logging of the data

**Corresponding author: Email: anekechikezies@uniuyo.edu.ng, chykeneketon@gmail.com;*

collected. This work is targeted toward the weather forecasting sector, agricultural sector, and individuals which may wish to gather information about the atmosphere for knowledge consumption. The results show that this device has a good performance for capturing atmospheric parameters for real-time monitoring purposes.

Keywords: Data acquisition; capturing device; climate; sensor; weather.

1. INTRODUCTION

Information from the physical world is gathered using a weather-acquisition device. Weather acquisition device is an atmospheric measuring device that can be sent up into near space to conduct experiments and is used for collating and gathering atmospheric parameters like pressure, temperature, humidity, wind speeds, air quality, etc [1]. The technological advancement in weather predictions has shown the need for accurate measurement of atmospheric parameters which is of utmost importance to meteorologists. Of recent, there is a need for observing atmospheric weather parameters that will make scientist have access to real-time data they need to forecast or predict atmospheric weather conditions [2]. The need for accurate meteorological forecasts is on the rise because some sectors are in need of accurate weather prediction like the agriculture sector, maritime sector, and aviation sector. Correct weather prediction is very important in forecasting dangerous weather conditions in order to put up preventive measures.

The first weather instrument, the thermometer was invented, followed by the barometer towards the end of the sixteenth century in 1643, and then the hygrometer, which was invented in the late seventeenth century for measuring humidity [3]. These led to the development of more weather instruments and weather measurements became more precise and reliable. Guidelines for the installation, implementation and usage of atmospheric capturing devices were published by the World Meteorological Organization (WMO) in a series of Conferences with regard to instructions about climatic data acquisition, which included the exchange of data between Meteorological Services as well as measurements [4].

Different instruments have been developed for atmospheric measurements. This is categorized into the in-situ measurements group and the remote sensing group. Usually, remote sensing instruments use the emissions or scattering of electromagnetic waves to determine the condition of the atmosphere such as light from the atmosphere with a high temporal resolution. For in-situ instruments, it can be ground-based or attached to radiosondes or aircraft. A report by the National Research Council and Instrumentation Workshops [5] states that monitoring systems capable of giving detailed humidity, temperature, and wind profiles within the atmospheric boundary layer are urgently required to monitor the lower atmosphere, investigate, and determine the potential for weather monitoring and forecasting. Rising sea levels and precipitation patterns, temperature, and more extreme weather changes threaten food and water security, human health, security, and socioeconomic development on the continent. For this reason, accurate and up-to-date data is needed for adaptation planning that will help to curb these natural occurrences and seek to proffer a positive prediction of weather. The Design and Implementation of a Weather Acquisition Device that will be able to fly up to the troposphere where most of the weather condition occurs, record and process data for more precise real-time weather forecasting, and transmit the information to Think Speak Web via the cloud.

The paper, design, and implementation of a microcontroller-based weather acquisition device shows Section 1 detailing the introduction and related work, Section 2 detailing the materials and methods for the weather acquisition device, Section 3 detailing the observed Findings and discussions, and section 4 provides the conclusion.

1.1 Related Works

Low-cost weather monitoring systems and stations such as those in this work have recently been proposed and implemented worldwide, some of these proposed devices have one or more improvements in terms of design, cost, and correctness.

In [6] the author talks about the models needed to produce weather forecasts and details of the processes required in weather forecasts. However, the proposed method uses microcontrollers and sensors to monitor atmospheric variations and predict the weather. Therefore, the Related Works section shows existing studies and their limitations in monitoring climate change. Ukhurebor K, et al. [7] propose a low-cost weather-monitoring device that uses Arduino Mega 2560 and other devices to monitor temperature, pressure, humidity, and light intensity. Dr. Bindhu [8] designed and developed an automatic microcontroller-based weather forecasting device that uses weather Pi Arduino V3 w/Groove and other sensors to measure wind speed, temperature, humidity, and pressure. Kirankumar Sutar [9] designed a cost-effective weather monitoring system that uses a ZigBee radio communication module and other sensors to monitor temperature, humidity, and light intensity.

Nisha G et al. [10] also made use of ZigBee wireless technology and other sensors to monitor temperature, humidity, light intensity, and raindrop. Wanogho et al. [11] make use of an ESP32 microcontroller and other sensors to monitor weather conditions like humidity, temperature, and light intensity. Shilpa Chaman [12] designed a ZigBee-based temperature monitoring and control system that makes use of an Atmega16 microcontroller and ZigBee transceiver to monitor the temperature. Shalabh Singh et al. [13] designed a microcontroller-based room temperature monitoring system using Atmega8535 and LM35 temperature sensors.

An IoT-based weather station with embedded system was developed by Olanrele et al. [14] using ESP8266/Nodemcu to monitor temperature, humidity, and light intensity. Rajesh Singh et al. [15] designed a temperature monitoring device in a wireless sensor network using ZigBee transceiver communication module with IC-CC2500 and 2.4GHz as RF transceiver to monitor temperature. Kamarul et al. [16] designed a low-cost microcontroller-based weather monitoring device that measures atmospheric pressure, humidity, and temperature using microcontrollers and sensors. A wireless mobile microcontroller-based weather monitoring device was designed by Devaraju et al. [17] using a PIC16f887 microcontroller and other sensors to measure.

2. MATERIALS AND METHODS

The proposed device called a weather-acquisition device is made up of three main parts: a group of highly developed meteorological sensors called the data acquisition module, signal-processing circuits called the data processing module, and a radio transmitter that transmits measurements back to a receiver at the location where the weather station was launched called the communication module. The intervals between meteorological measurements might range from 1 to 6 seconds, depending on the type and maker of the weather station. The suggested model creates a weather- acquisition device to capture atmospheric parameters using sensors. The sensors are used to measure atmospheric changes every minute and the information sent to the web server for immediate access by users, providing a precise forecast of the weather by using Thing Speak IoT platform as a display.

The materials and components used in the design of this project are:

1. ESP8266: Microcontroller that connects the sensor data to your Wi-Fi, and sends data to the web server.
2. BME280: Sensor for Temperature, Humidity and Pressure
3. NEO6m: GPS for longitude and latitude
4. TP4056: Power supply, lithium polymer battery
5. 3D Printed enclosure

2.1 Data Processing Module (ESP8266)

The ESP8266 is developed by Espressif Systems and is a low-cost Wi-Fi chip. It can be used as a stand-alone device or as a UART to Wi-Fi converter to allow other microcontrollers have access to a Wi-Fi network. For example, to add Wi-Fi functionality to your Arduino board, you can connect an ESP8266. Much like you can control inputs and outputs with an Arduino, the ESP8266 has Wi-Fi capabilities.

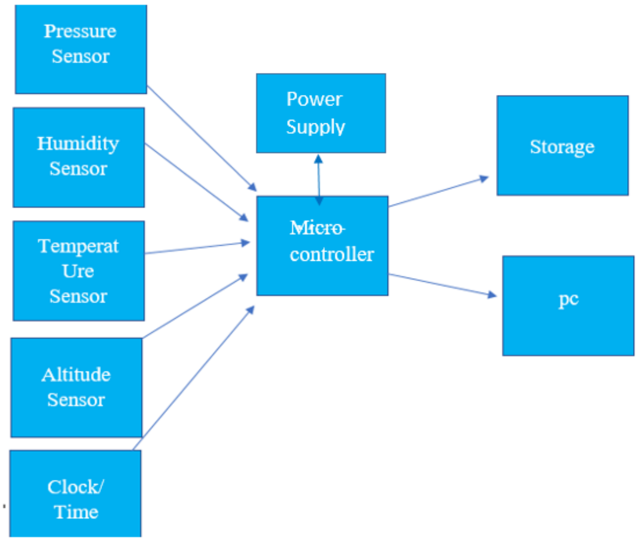

Fig. 1. Conceptual Design of the Capturing Device

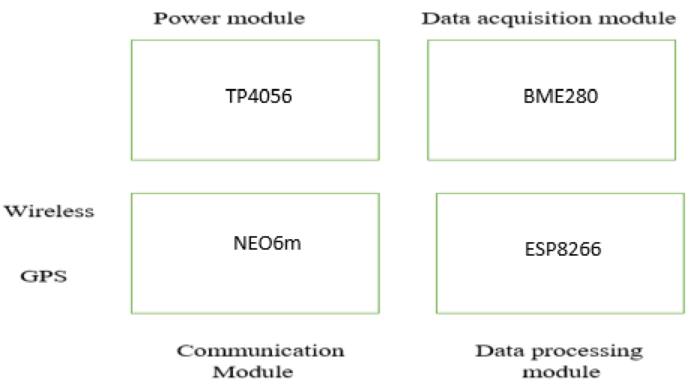

Fig. 2. Block Diagram of the Capturing Device

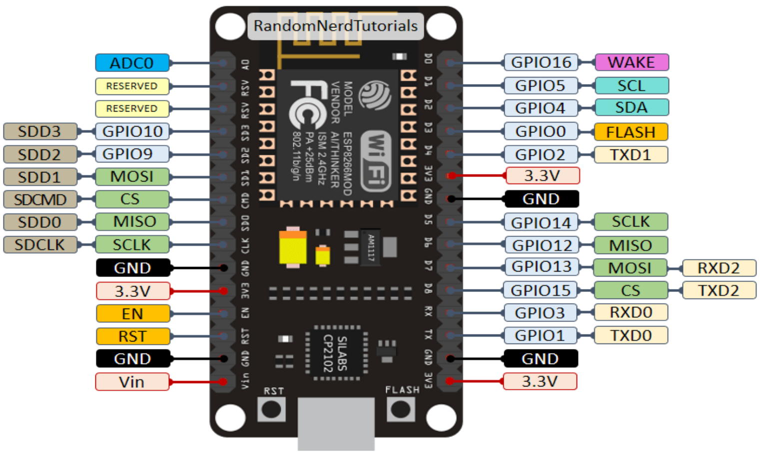

Fig. 3. Pinout Diagram of ESP8266

Fig. 4. Diagram of BME280

Features of ESP8266

- The CPU is based around ESP8266 at 240MHz dual-cord
- Wi-Fi is up to 150Mbps 802.11 b/g/n/e/h, direct P2P soft app
- Has a flash size of 4MB (32Mbit)
- Uses CP2102 as the USB-Serial converter
- It uses Semtech SX1276 Radio module
- It uses an external antenna connector: IPX (UFL)
- Integrated TCP/IP protocol stack
- Built-in low-power 32-bit CPU

2.2 Data Acquisition Module (BME280)

The BME280 is a humidity sensor specifically designed for wearable and mobile applications where size and reduced power consumption are key design factors. Low power consumption, long-term stability and high EMC robustness can be perfectly achieved with the combination of highly linear and high-precision sensors.

Features of BME280

- High accuracy
- Easy-to-use Grove Compatible Interface
- Supports both I2C and SPI communication
- Can be used as an altimeter with an accuracy of ±1 meter and low altitude noise of 0.25m
- **Pressure and temperature range**
  - Pressure range: 300hPa to 1100 hPa with an absolute accuracy of ±1 hPa.
  - Temperature range: -40 to 85℃ with an accuracy of ±1 hPa
  - Humidity Range: 0 to 100% RH (±3% accuracy)
  - **Power consumption**: 1mA (typ.) and 5µA (idle)
  - **Sensor Size: 15mm x 12mm x 5mm**

2.3 Data Communication Module (NEO6m)

The NEO-6M module is a powerful full-featured GPS receiver with a ceramic antenna built-in 25 x 25 x 4mm that provides a powerful satellite search function. NEO-6M GPS chip is the heart of the module from u-blox. The chip packs a surprising number of functions into its small frame and measures less than a postage stamp.

Unlike other GPS modules, it has a horizontal position precision of 2.5m and can update its location up to 5 times per second. The Time-To-First-Fix of the u-blox 6 positioning engine is also sub-one second (TTFF).

Features of NEO-6M GPS module

- High sensitivity for tracking
- Low supply current (~45mA)
- Operating temperature range: -40 TO 85°CUART TTL socket
- Is able to track 5 locations per second with an accuracy of 2.5m (horizontal).

- Comes equipped with PSM also known as Power Saving Mode. This mode causes very less power consumption by turning the module ON/OFF according to the need.
- Rechargeable battery for Backup
- The cold start time of 38 s and Hot start time of 1 s
- Supply voltage: 3.3 V

2.4 Power Module (TP4056)

This lithium-ion battery is rechargeable and makes use of a polymer electrolyte rather than a liquid one. High-conductivity semi-solid (gel) polymers make up this electrolyte. Compared to other lithium battery types, these batteries offer a higher specific energy output.

The TP4056 charging module is a compact charging module for lithium-ion batteries. Using an IC and a few discrete components, we create a high-quality charging module that can provide the required charging behavior for Lithium-Ion batteries, allowing them to extend their useful life and provide a complete backup power supply.

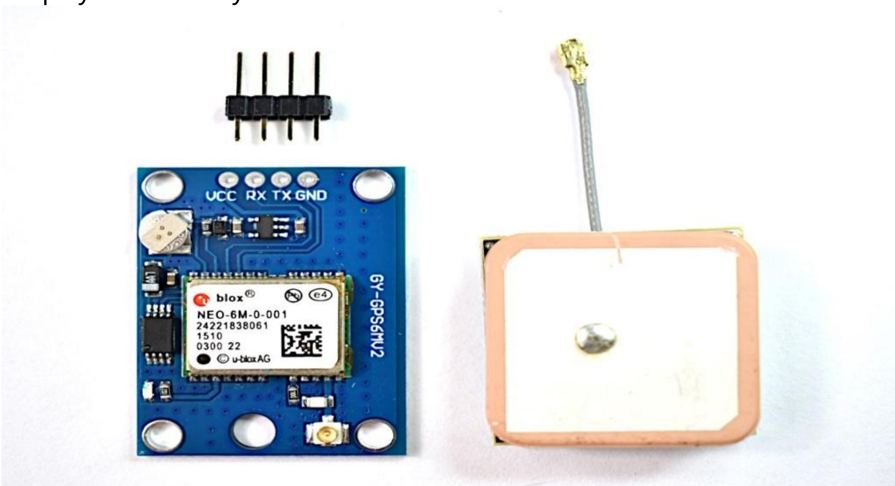

Fig. 5. Diagram of a NEO6M GPS Module

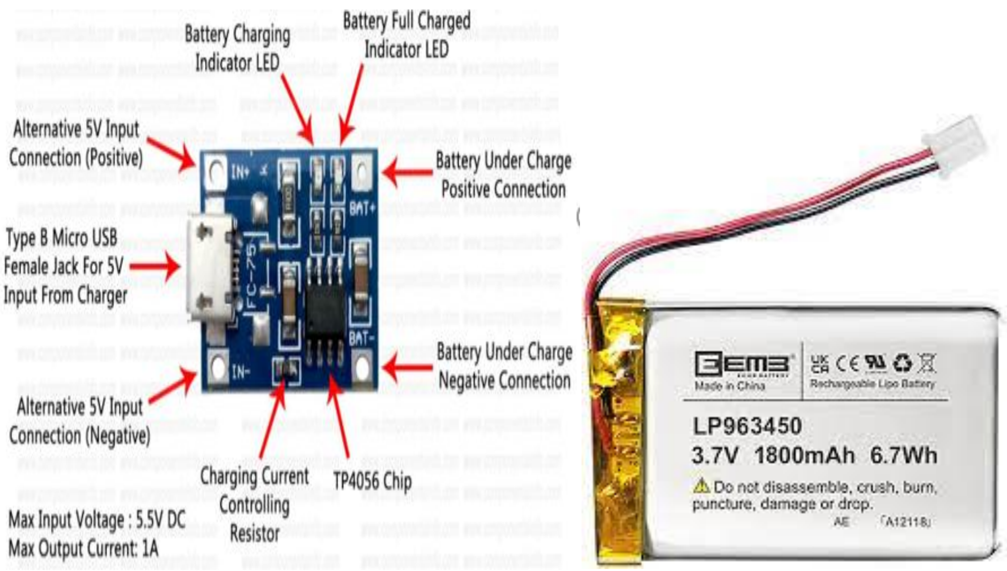

Fig. 6. Diagram of a lithium Battery and charger

Features of Power Module TP4056

- Low weight
- Higher energy density for a given weight (WH/kg)
- Slightly higher top usage temperature.
- It can charge any size of 3.7V Li-ion cell
- Low-cost and reliable Li-ion battery charger
- Battery temperature measurement inside (Disconnect charging when the temperature of the battery goes high than normal)
- Can connect to any USB port with a USB cable
- Power: 4.2 w.
- Charging accuracy: 1.5%
- Operating Temperature: -10 to +85°C.
- Input voltage: 4.5V ~ 5.5V.
- A full charge voltage: 4.2V.

2.5 A Web Server

A web server is where the resources of a website reside, it can be a local host or a remote host, the local host can sometimes suffer from proper maintenance and live data feed. The remote type is more reliable as they are mostly paid services that are properly maintained so that data can be sent or retrieved at any time without any complications. Thingspeak web server is a host for lots of data related to data logging as it has some analysis tools that help in processing the data logged on the web server. The Thingspeak web server is owned by Mathworks. You need an active account before you can publish sensor data on your web server.

3. RESULTS AND DISCUSSION

Typically, a weather station is a device consisting of sensors that take the atmospheric measurements at different levels of the atmosphere and transmit them by radio to a base station on land or water and use the result for weather forecasting or to predict natural disasters such as hurricanes, tornadoes and the like that can destroy lives and property.

A microcontroller connected to sensors that can read temperature, humidity, pressure and altitude is then programmed to take such readings in the fastest possible time, typically between one hundred milliseconds and five seconds, as a physical quantity and these faint signals then amplified using a cascaded amplifier configuration and then later convert these amplified readings of physical quantities into electrical impulses which in most cases appear in analog form since their readings vary over time.

The electrical pulses are then converted into a digital signal that can be read by a microcontroller using an analog-to-digital converter built into the microcontroller's circuitry for this function. The signal is then processed by the microcontroller's arithmetic and logic unit (ALU) to perform calculations and return a result of the measured physical quantity. Most often the results are compared to some standard to determine if the result is correct before its answer is validated as correct, or if it needs to be corrected by the error amplifier. The result is now ready to be sent. Before connecting the sensor to the microcontroller, a bootloader must first be loaded onto the microcontroller, the first time it is used, the chip is then ready to be programmed thousands of times depending on the read and write cycles.

The booted microcontroller is then connected to a network capable of transmitting data over long distances, one such network is the Lora gateway, which allows long-distance radio communication with constant connectivity. An example sketch is uploaded to the microcontroller to test its functionality before the firmware is uploaded to it. The uploaded firmware took care of the data transfer and internet connection between the microcontroller and the remote server used to publish or log the weather data.

The device is encased in an inexpensive 3D-printed case so it can shield the weather-capturing device's components while leaving the sensors outside to read the atmospheric data. In order for the weather station to take the vertical profile measurements, it can either be attached to a drone or a glider.

The basic atmospheric elements in Atmospheric Boundary Layer detection include Pressure, humidity, and temperature. In this project, an atmospheric parameter capturing device was developed based on the actual need for atmospheric weather parameters Pressure, humidity, and temperature as well as altitude, latitude, and longitude. The figure shows the structural design of the atmospheric acquisition device.

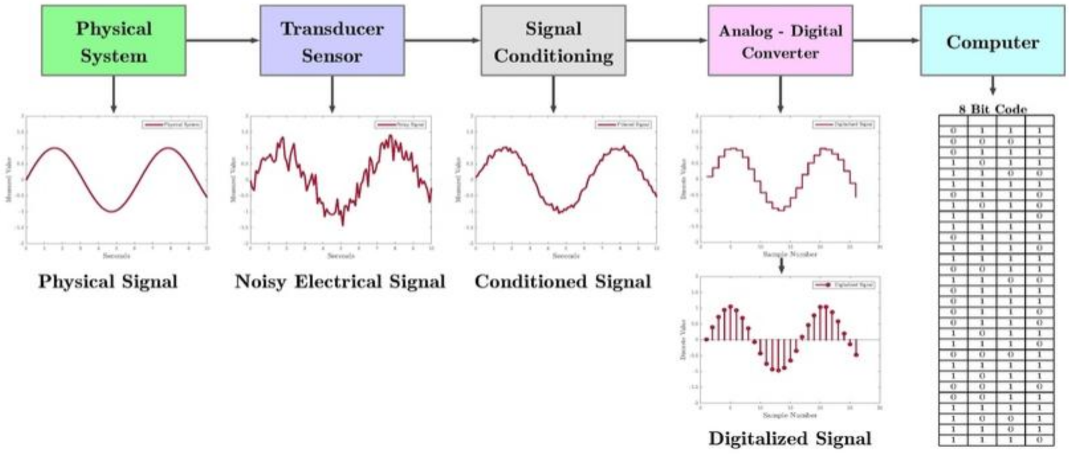

Fig. 7. The Data Acquisition process

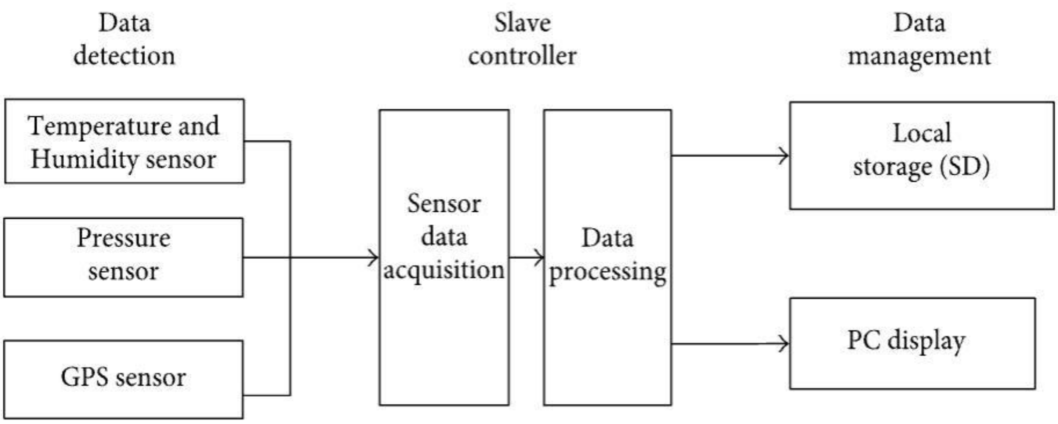

Fig. 8. Atmospheric Weather acquisition device structural design

The hardware circuit is the foundation of the whole detection platform, and its design needs to consider many aspects, such as working environment and component model selection., and only reasonable development of the entire hardware circuit can finish the work of the hardware system of this weather-acquisition device. NEO-6M GPS module has an LED that shows the status of the positioning. When there is no blinking, it is searching for satellites, when it blinks for 1 second: the position is found.

The design involves the weather-capturing device made up of ESP8266 that connects the sensors and sends data to your browser. It also processes the weather data collected such as temperature, humidity, pressure, altitude, longitude and latitude using the BME280 sensor. TP4056 and lithium polymer battery serve as the main power to the device, and NEO-6M captures the longitude and latitude. The Microcontroller processes the information captured, the Wi-Fi router, and the 4G cellular and network modem convey the processed information to the web server. The schematic diagram below shows how the components were soldered.

The atmospheric parameter weather-acquisition device includes temperature and humidity sensing, pressure sensing, and geographic coordinate sensing. The communication mode of the atmospheric element detection sensor was as follows: Temperature and humidity were sent over one bus, pressure was sent through his I2C in an ESP8266 microcontroller, and altitude, latitude, longitude and west African time were sent through a serial port.

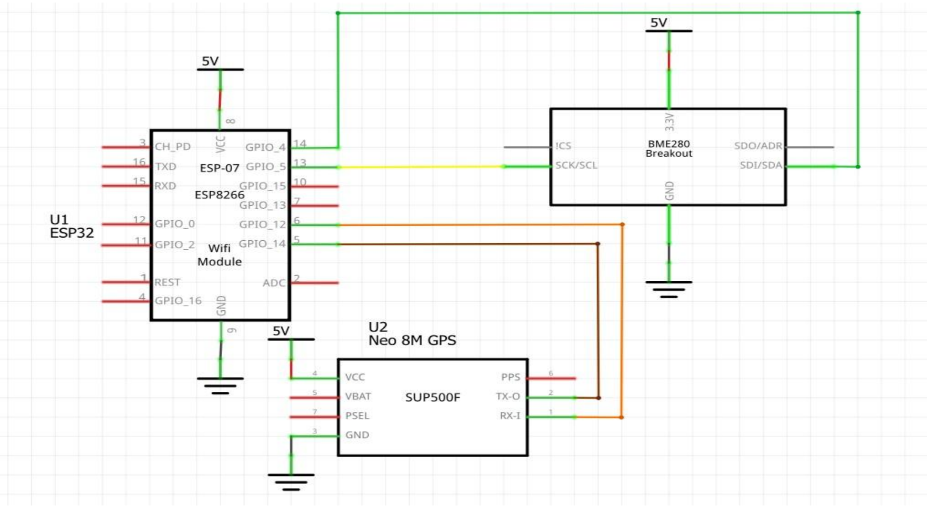

Fig. 9. Schematic Diagram of the weather Capturing Device

Fig. 10. The Weather Acquisition Device

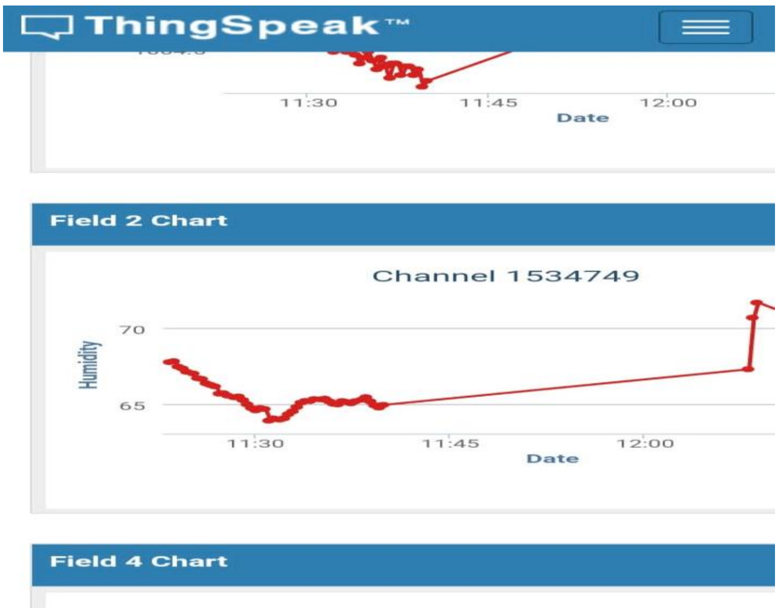

Fig. 11. Humidity screenshot from Thingspeak

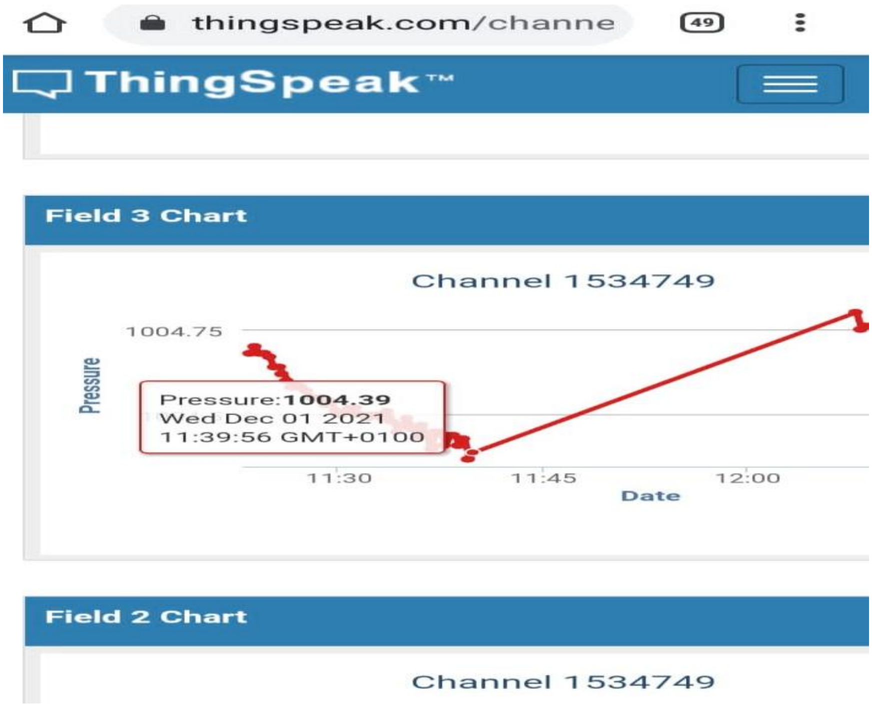

Fig. 12. Pressure screenshot from Thingspeak

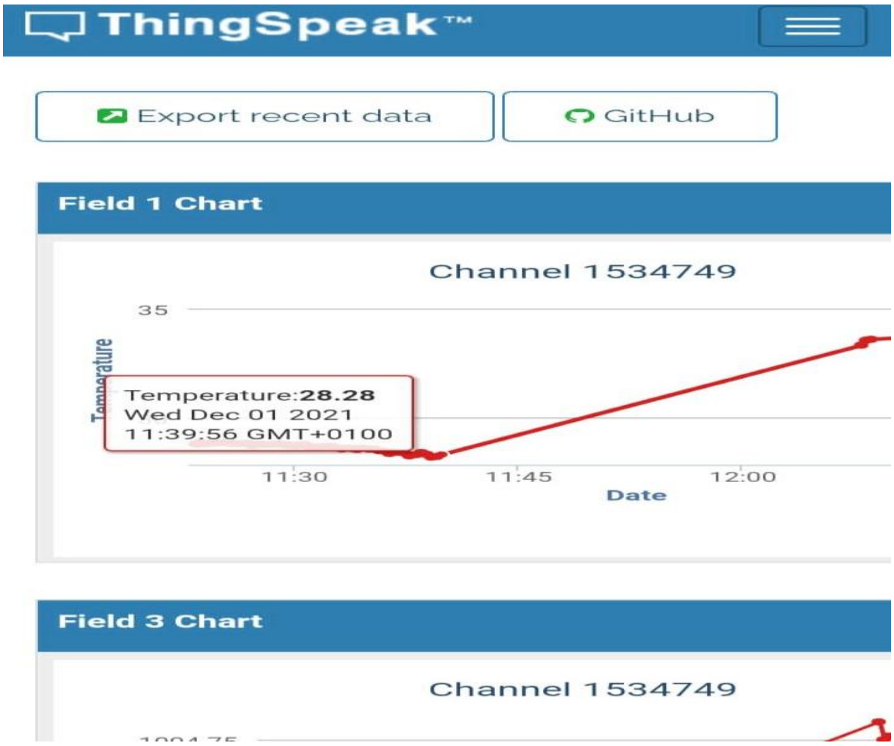

Fig. 13. Temperature screenshot from Thingspeak

The screenshots above were taken by the Thingspeak web server and show the data collected by the weather collection device. The data captured in Thingspeak was converted to CVS format in the figure below for easy export and usage.

	A	B	C	D	E	F	G	H
1	created_at	entry_id	field1	field2	field3	field4	field5	field6
2	2021-12-01 10:09:02	599	29.47	82.2	1004.93	69.49	0	
3	2021-12-01 10:09:23	600	29.53	81.73	1004.9	69.72	0	
4	2021-12-01 10:09:44	601	29.44	81.04	1004.87	70.03	0	
5	2021-12-01 10:10:05	602	29.94	80.92	1004.86	70.11	0	
6	2021-12-01 10:10:26	603	29.6	79.6	1004.89	69.81	0	
7	2021-12-01 10:10:46	604	29.66	79.1	1004.88	69.89	0	
8	2021-12-01 10:11:07	605	29.59	78.44	1004.92	69.62	0	
9	2021-12-01 10:11:28	606	29.62	77.98	1004.89	69.85	0	
10	2021-12-01 10:11:50	607	29.52	77.32	1004.88	69.92	0	
11	2021-12-01 10:12:10	608	29.47	76.82	1004.85	70.14	0	
12	2021-12-01 10:12:31	609	29.46	76.38	1004.86	70.05	0	
13	2021-12-01 10:12:52	610	29.4	75.89	1004.87	69.98	0	
14	2021-12-01 10:13:13	611	29.32	75.41	1004.84	70.26	0	
15	2021-12-01 10:13:34	612	29.31	75.05	1004.87	70.03	0	
16	2021-12-01 10:13:55	613	29.31	74.73	1004.84	70.24	0	
17	2021-12-01 10:14:16	614	29.01	74.13	1004.87	70.01	0	
18	2021-12-01 10:14:38	615	29.14	74.05	1004.86	70.07	0	
19	2021-12-01 10:14:59	616	29.17	73.77	1004.83	70.35	0	
20	2021-12-01 10:15:20	617	28.95	73.24	1004.82	70.45	0	

Fig. 14. CVS format of the data captured by the device

The weather-acquisition device was tested by continuously monitoring the atmospheric parameter changes with sensors. The output of the monitored atmospheric parameters weather changes is reported from the 4G networks to the Thingspeak web, verifying the accuracy of the developed model. The results are shown above present the data monitored and reported via Thingspeak.

4. CONCLUSION

The design and implementation of the weather-acquisition device is a project focused on allowing users to access real-time atmospheric weather data anywhere. This paper demonstrates the design and implementation of a weather-acquisition device that can record data on some weather variables such as pressure, temperature, humidity, altitude, latitude, and longitude with a real-time data logger. This paper provides data for forecast and once the weather-capturing device is connected, the user can also view the information history. This data can be used to analyze weather patterns and make predictions about future weather conditions such as the likelihood of storms or other extreme conditions.

ACKNOWLEDGEMENTS

We wish to thank God for making this a success. No funding was used for this paper.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Illingworth AJ, Cimini D, Gaffard C, Haeffelin M, Lehmann V, Löhnert U, et al. Exploiting existing ground-based remote sensing networks to improve high-resolution weather forecasts. Bulletin of the American Meteorological Society. 2015;96(12):2107–2125
2. Konstantinos L, Dimitris K, Petros A, Vasileios A, and LLias K. Low-cost automatic weather station in the internet of things, Information. 2021;12(4):146.
3. Ahrens, C.D. Meteorology Today, 9th ed.; Brooks, Cole, Cengage Learning: Belmont, CA, USA; 2009.
ISBN 0-495-55573-8.
4. Flokas A. Lessons in Meteorology and Climatology; Ziti Publications: Thessaloniki, Greece; 1992.
5. Hoff R, Hardesty R, Carr F, Koch S, Weckwerta T et al Thermodynamic Profiling Technique workshop NCR; 2012.
6. Ibeh AJ, Woma TJ. Weather Forecasting Models, Methods and Applications. International Journal of Engineering Research and Technology. 2013;2(12):ISSN: 2278-0181.
7. Ukhurebor K, Abiodun I, Azi S, Otete I, and Obogai E, A Cost Effective Weather Monitoring Device, Archives of Current Research International. 2017;7(4):1 – 9. ISSN:2454-7077
8. Bindhu V, Design and development of Automatic Microcontroller-Based Weather Forecasting Device, Journal of Electronics and Informative. 2020;2(1):1-9.

9. Kirankumar Sutar, Low-Cost Wireless Weather Monitoring System, International Journal of Engineering Technologies and Management Research. 2015;1(1):ISSN: 2454-1907
10. Nirsha G, Varsha G, Sonali K, and Archana T, ZigBee-Based Weather Monitoring System, International Journal of Engineering and Sciences. 2015;4(4):61-66. ISSN:2319-1805
11. Wanogho J, Ogbeide K, Agbotean I, Development of ESP32 Based Weather Monitoring System for Photo Voltaic Yield Characterization in Delta State Nigeria, International Journal of Engineering Science Invention. 2022;11(4):12-18. ISSN: 2319-6726
12. Shilpa Chaman, ZigBee Based Temperature Monitoring and Controlling in Matlab, Asian Journal of Electrical Science. 2013;2 (1):1-4. ISSN: 2249-6297
13. Shalabh Singh and Shripad Desai, A Microcontroller-Based Room Temperature Monitoring System, International Journal of Innovative Research in Technology. 2020;7(7):ISSN: 2349-6002
14. Olanrele O, Adeaja O, Adeyemi O, Ajayi O and Mowemi A, An IOT Based Weather Station using an Embedded System, Quantum Journal of Engineering, Science and Technology. 2020;3(3):31-40 eISSN: 2716-6341
15. Rajesh Singh and Shailesh Mishra, Temperature Monitoring in Wireless Sensor Network Using ZigBee Transceiver Module, IEEE International Conference on power, control and Embedded System; 2010.
16. Kamarul A, Chow C, and Mohamad F, A low Cost Microcontroller-based Weather Monitoring System. CMU. Journal. 2006;5(1):33.
17. Devaraju J, Suhas K, Mohana H and Vijaykumar A, Wireless Portable Microcontroller-based Weather Monitoring Station. Informa-Interdisciplinary center for mathematics and Computational Modelling. 2015;189-200:ISSN:0263-2241.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/97146