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Design and Implementation of a LoRa Technology - Based Smart Home Monitoring Circuit



Abstract: - This paper offers a detailed design and real-world execution of a complex electrical circuit for smart homes that employs LoRa technology to monitor significant environmental conditions and the operating state of home equipment. The circuit's novel design allows it to monitor power usage and the on/off state of home appliances, in addition to measuring temperature and humidity with extreme precision. With its reputation for long-range and low-power wireless communication, LoRa technology is used by the core microcontroller of the system, which also processes sensor data. This is why the system works particularly effectively in large residences where other wireless technologies would have trouble. The solution ensures consistent and dependable data transmission using LoRa, even in the face of the common architectural obstacles seen in residential environments. To facilitate data analysis and remote monitoring, an electrical circuit was made to be readily linked to a central hub for home automation. A comprehensive assessment procedure was used for implementation in different household environments to determine responsiveness, dependability, and user-centered design. The empirical findings demonstrate how well the circuit works to provide homes with practical advice on how to best regulate device use and optimize the interior temperature, which eventually improves comfort and energy efficiency. To achieve next-generation home automation systems, LoRa-based solutions are critical, and the article concludes by analyzing the consequences of this study on the future landscape of smart-house technologies.

Keywords: LoRa, LoRaWAN, DHT11, Arduino Mini, Smart home, Temperature, Humidity.

I. INTRODUCTION

The idea of "smart homes" has gradually changed because of the incorporation of Internet of Things (IoT) gadgets, with the goal of improving ease and energy efficiency in living areas. The design exemplifies this advancement; it includes a circuit that gathers and processes environmental data while also facilitating communication with the home automation center. This is a central point that provides remote monitoring, controls and data analysis for intelligent decision making to enhance the quality of lives. This paper outlines step-by-step instructions for designing the circuit, selecting the microcontroller, integrating sensors and using LoRa for communication

The details of selecting the appropriate parts and designs for a reliable and affordable circuit are covered in detail in this article. It walks you through the factors to consider when choosing a CPU, including things like processing speed, power efficiency, and compatibility with LoRa modules. In order to provide real-time control and monitoring, the circuit itself attracts sensors for motion, temperature, humidity and device status. For those who want more information, the Implementation section explains setup, calibration, and testing procedures. It all comes down to the long range and low energy usage. LoRa has the capabilities to address historical issues and maintain robust connectivity over long distances, especially in smart homes [1-5].

This paper investigated the integration of the circuit with the home automation hub in great depth, including topics such as remote access protocols, communication protocols, and data format standards. Predictive modeling and data analysis approaches for comfort and energy efficiency are also explored, and improvements in battery life, communications range and sensor accuracy are revealed through circuit performance analysis of real smart homes. The system reduces energy consumption, controls device use, enhances user comfort, and optimizes the interior environment. With the use of LoRa technology and a carefully selected microcontroller, the circuit successfully monitors and controls home surroundings, particularly in residential areas, marking a major leap in smart-home technology. Artificial intelligence may be used in future research to enable automated decision-making and sophisticated data processing [6-9]. The proposed system is illustrated in Figure 1.



Figure 1: Main Diagram of the LoRa Network for the suggested design

II. LITERATURE REVIEW FOR LoRa TECHNOLOGY APPLICATION

LoRa technology is a wireless communication protocol that is perfect for Internet of Things (IoT) applications because it can transmit data over vast distances while using little power. Devices can run on battery power for years owing to this system, which comprises of end nodes, gateways, and a network server. The sub-gigahertz frequency ranges, such as 868 MHz in Europe and 915 MHz in North America, are where the LoRa works. It provides capabilities such as geolocation and encryption without requiring large capacity. It is appropriate for devices that must communicate over long distances or in challenging RF situations, because it functions well in both indoor and urban areas. LoRa offers a more connected world than ever before as the foundation for contemporary IoT installations. Figure 2 shows the architecture of the LoRaWAN network.

This section presents a group of papers and similar studies that use LoRa technology.

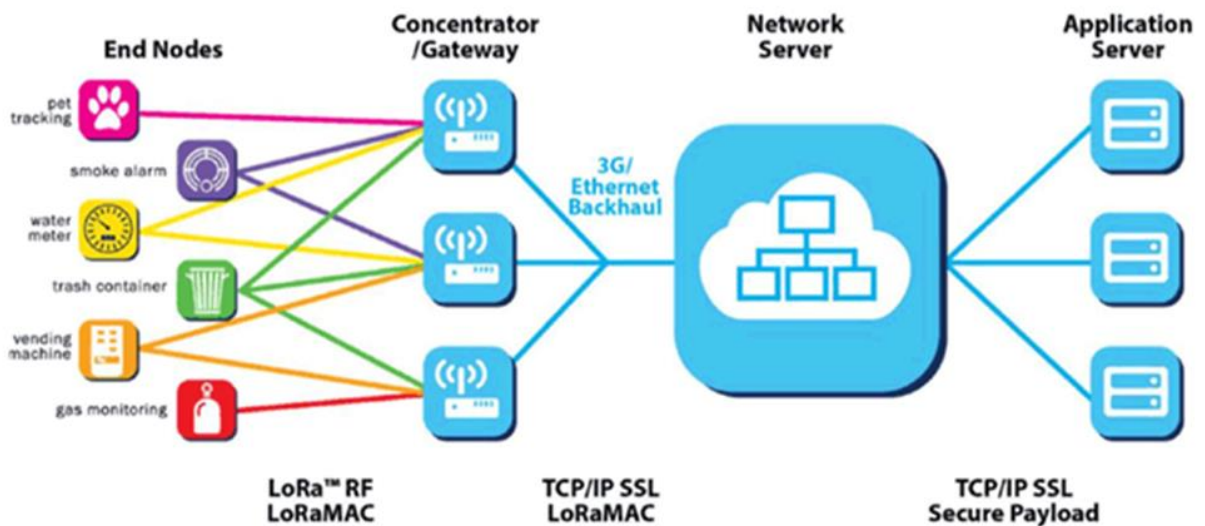


Figure 2: LoRaWAN-Network-Architecture diagram [10]

E. Gambi, L et al., 2018 [11]. In this paper, Smart Home apps use an increasing number of Internet of Things (IoT) technologies to enable communication between smart gadgets and the external environment. One of the main issues in developing and deploying the IoT infrastructure is battery consumption. This paper describes a LoRa-based IoT-oriented architecture for smart homes built for intermittent transmission, low power consumption, and interference resistance. For device communication, the Message Queue Telemetry Transfer protocol serves as demotic middleware.

K. Kim et al., 2021 [12]. In this paper Industry 4.0 and smart homes have seen a rapid expansion of the Internet of Things (IoT), with indoor localization emerging as a critical component. Indoor localization is achieved using low-power wireless technologies, such as Bluetooth, RFID, LoRa, UWB, and WiFi. Nevertheless, indoor localization using LoRa has not been thoroughly investigated at the household level. The goal of this study is to determine whether the range using LoRa is feasible and to show that it can provide exact indoor localization in an apartment situation.

A. E. Akin-Ponnle et al., 2023 [13]. In this study, a low-energy Smart Turbine Energy Harvester (STEH) for wind that can be used in smart cities and buildings is a Home Chimney Pinwheel (HCP). These pinwheels, which have low inertia to the wind and can be mounted on roofs, are often used as outside covers for residential chimney exhaust outlets. The IoT analytic cloud platform "ThingSpeak" allows the HCP to remotely monitor and control low-power IoT devices using LoRa transceivers.

H. Liu et al., 2018 [14]. In this study, we used a senior-centric smart home system based on LoRa to address issues of reliability in terms of data collection and transmission. A privacy-preserving data aggregation scheme was applied whereby encryption keys and shared secret keys are generated by the system without a requirement of trusted authority center. Data integrity was ensured by fault tolerance and batch verification. The theoretical analysis demonstrates its more accurate, secureness than prior methods while also requiring less processing power. The software is meant to enhance seniors' quality of life by leveraging on what smart homes technology has to offer them.

J. Han et al., 2020 [15]. This study suggests a long-term posture detection method with multi-sensory integrated clothing based on LoRa technology in smart cities. It is low cost and has long transmission range due to Lora WAN technology which has been implemented in many wearable clothing items that have transmitting module embedded in them. Multi-processing strategy included data expansion, feature extraction, Random Forest selection, denoising etc.. The method achieved 99.38% accuracies after training with 3239 datasets for extracted features and reached 95.06% accuracies for selected features as well. LoRa's exact localization and energy sustainability make this approach ideal for long-range detection in smart cities, particularly for long-distance transmissions

L. Kane et al., 2022 [16]. In this work we present a home area network architecture based on 2.4 GHz LoRa technology together with ChaCha20-Poly1305 authenticated encryption with associated data (AEAD) based authentication technique. A comparison was made between sincerity/secretcy/authenticity characteristics against performance metrics. A performance assessment showed that having a secure architecture did not affect network response time compared to a network with no security.

A. Cano-Ortega et al., 2020 [17]. his paper introduces a performance improvement strategy using an artificial bee colony oriented to a long-range (LoRa) network for enhanced performance. Since it's packet loss rate is low, this method leads to lower data transmission together with more accurate home load profiles. Moreover, there are smart meters in the system for domestic load profiles that enable demand forecasting, energy tariff optimization and household consumption analysis.

Nur-A-Alam et al., 2021 [18]. A novel intelligent automation system for the remote management and monitoring of commercial, institutional, and residential equipment was unveiled in this study. The long-range LoRa technology helped it. This system consists of sensors and wireless communications. The device was controlled via a smartphone application and operated on a low-power battery. The Android phone and the ESP32 microcontroller were connected to the system via Wi-Fi, and the switching was managed using the WAN communication protocol. In real-life case studies, the system performed well, achieving 90% accuracy for environmental data and 92.33% accuracy for task switching.

III. SYSTEM REQUIREMENTS

A. *Selecting a Hardwar Requirements*

In this section, all electronic parts used in this study are discussed.

1. **Lora radio node v1.0.**

The LoRa Radio Node is an AVR Arduino board with an RFM95 LoRa module. This all-in-one LoRa module allows you to have a LoRaWAN device for a reasonable price. You need to add a battery (like an LS14500 3,7V battery) to the battery holder to make it mobile. LiPo options are also available using the power connector. Even if the connectors look like a grove, they are not compatible, so you will have to make your wiring to connect extensions [19].

Illustrated in Figure 3, the LoRa Radio Node v1.0 stands as a compact and versatile module specifically crafted for operation within sub-gigahertz radio frequency ranges. Its development signifies a milestone in innovative progress within the realm of wireless communication, serving a diverse range of applications—from the precision of asset tracking and the conveniences of smart homes to the rigorous demands of industrial monitoring and the nuances of agricultural sensors. This node possesses a unique capability: the transmission of small amounts of data across significant distances, a pivotal attribute in scenarios where conventional Wi-Fi or cellular networks encounter obstacles due to structural impediments or range limitations. Delving into its specifics, Table 1 enumerates the primary characteristics of the LoRa Radio Node v1.0.



Figure 3: Lora radio node v1.0. Module [19]

Property	Description
Frequency Band	433/868/915 MHz (region-specific)
Interface	UART, SPI, I2C
Output Power	Up to +20 dBm
Sensitivity	Down to -148 dBm
Range	Up to 2 km (line-of-sight)
Data Rate	0.3 kbps to 50 kbps
Input Voltage	Typically, 3.3V to 5V
Operating Temperature	-40 to +85°C

2. DHT11 Sensor.

The DHT11 sensor, shown in Figure 4, is a well-known digital temperature and humidity sensor that is praised for its ease of use and reasonable price. To measure temperature and humidity in ambient air, reading using a thermistor and capacitive humidity-sensing device were done. The humidity was sent as digital pulses through one data pin. The DHT11 has adequate accuracy for noncritical environment monitoring because its humidity measurement range is 20–80% RH and temperature detection span ranges from 0–50C [20]. The DHT11 is somewhat inaccurate with ±5 %RH error in humidity readings and ±2 °C error of temperature measurements. However, it is widely used by hobbyists and for educational purposes due to its ability to be integrated easily with microcontrollers like Arduino.

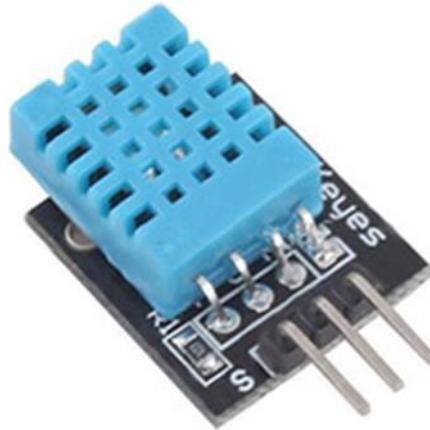


Figure 4: DHT11 Sensor Module [20]

This sensor consumes very little power, typically around 3-5V and a minimum of 0.3 mA during data acquisition, making it usable in DIY projects and low-power applications. It is designed to be physically small, presented in a plastic casing that is suitable for indoor environments where the presence of dirt particles or moisture may affect data accuracy. Despite its slower response rate and inability to function in harsh conditions, DHT11 remains widely used for basic climate monitoring in households, schools, and other areas where general trends are more significant than precise values.

3. Single Channel RELAY Module.

In Figure 5, there is a crucial part which controls high-power loads from low-power microcontrollers in electronics projects: The 5V Single Channel Relay Module. It has an electromechanical relay which can take care of AC or DC loads; additionally, it works with digital management devices like Arduino, Raspberry Pi, PIC etc. Screw terminals are available on-board jumper/dip switch for flexibility while LEDs signify that the device is switched on or off. This is essential for home automation, robotics, and DIY projects that require electrical isolation between the control circuitry and higher-power circuits [21].



Figure 5: Single Channel RELAY Module [21].

4. Power Supply Module Board (3.3V & 5V).

When working with microcontrollers and sensors, developers and electronics hobbyists must have access to the power-supply module board, as shown in Figure 6. It offers two separate regulated outputs and consistent clean voltage levels for broad applications. The board regulates the incoming voltage to the necessary outputs by drawing power from an external power source or normal USB connection. This indicates its operating state with LED power indication lights. Without the need for numerous power sources, this one board enables smooth power delivery to 3.3V and 5V devices. Its design, which incorporates screw terminals or pin headers, is simple to integrate into breadboard configurations, making it an indispensable prototyping tool [22].

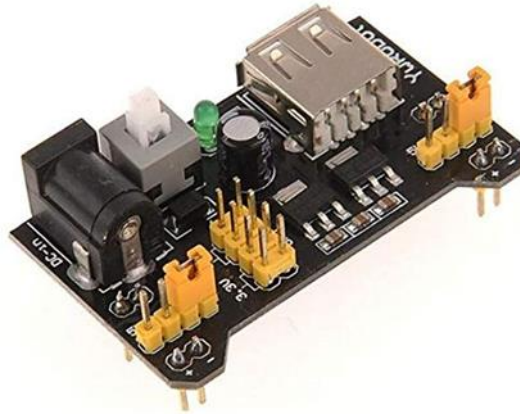


Figure 6: Power Supply Module Board [22].

5. LCD 20X4 with I2C LCD Controller Module

An easy-to-use method for adding a text interface to an electronics project is an LCD 20×4 display with an I2C LCD controller module, as shown in Figure 7 [23]. With 20 characters spread across four lines, there is more than sufficient room for lengthy messages, menu choices, and data readouts. By lowering the number of cables required and pin utilization on the microcontroller, the I2C controller module streamlines the connection procedure. The versatility of the module for global projects and applications stems from its support of both standard and custom-defined characteristics. It has a potentiometer-adjustable backlight to make it readable under various lighting scenarios. The text to be displayed may be easily sent to the display using programming libraries for systems such as Arduino.



Figure 7: LCD 20X04 with I2C LCD Controller Module [23].

B. Software Requirements

With its simplified version of C++, the Arduino Integrated Development Environment (IDE) in Figure 8 is an intuitive software platform that makes programming Arduino microcontrollers accessible to both novice and seasoned developers [24]. It has an output console, text editor, error message area, and toolbar, with buttons for frequently used operations. Additionally, a platform-neutral IDE works with popular OSs, including Windows, Mac OS, and Linux. It provides a large library of pre-written code segments or libraries that may be included in applications that manage motor control and internet connectivity. Serial monitoring is essential for debugging and viewing the data directly from a microcontroller. The IDE's inclusive community and extensive documentation make it an ideal Launchpad for prototyping, educational purposes, and hobbyist projects in electronics and IoT.

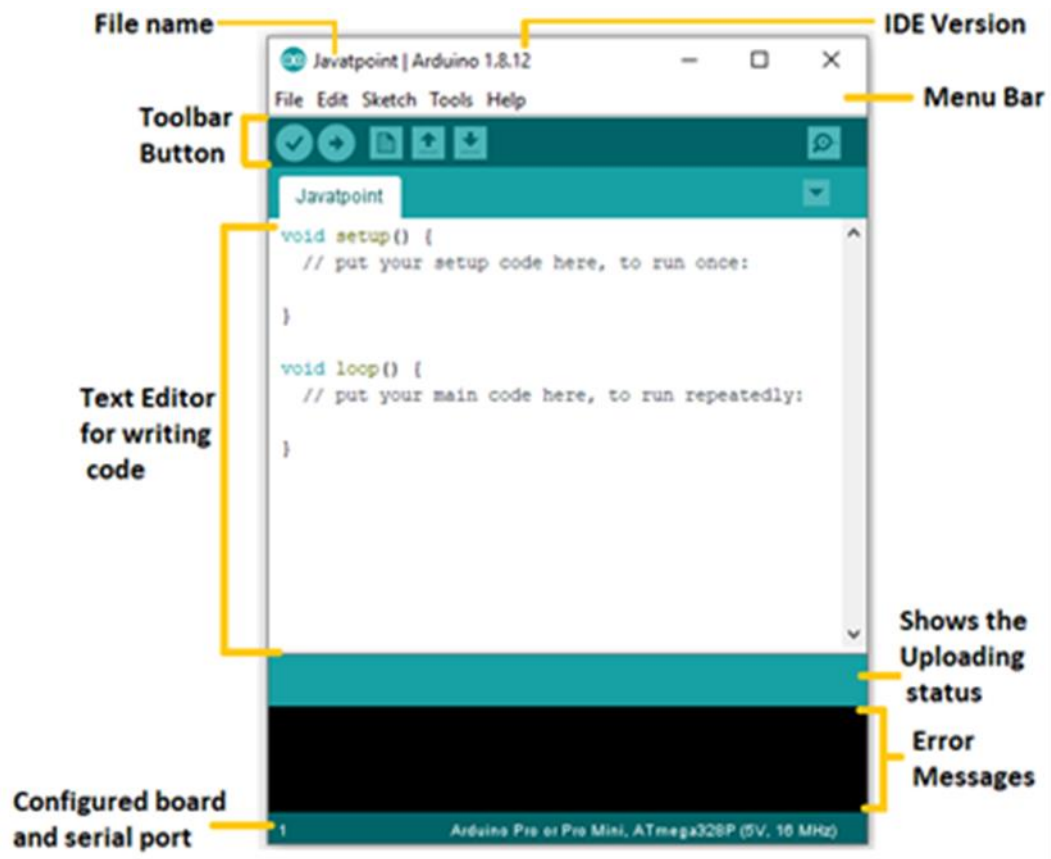
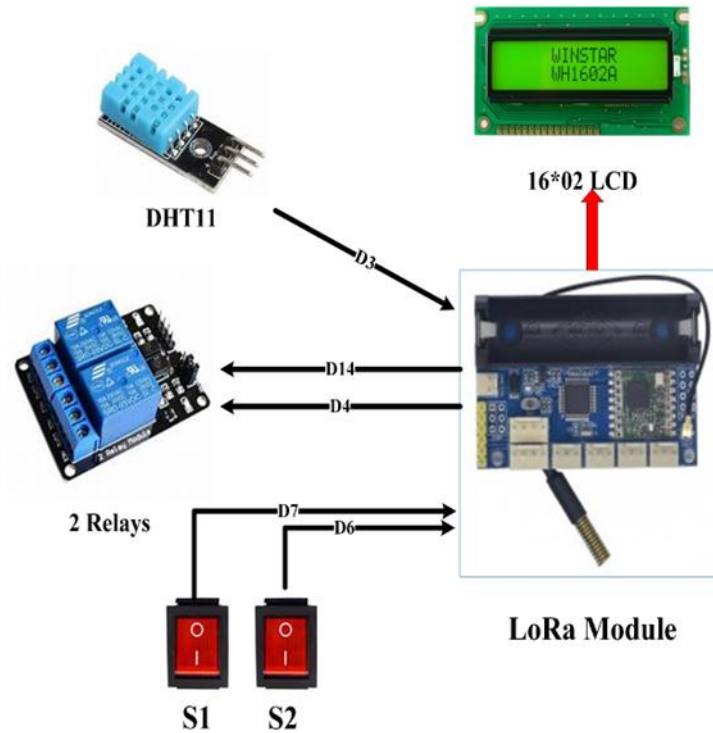


Figure 8: Main window of the IDE Platform

IV. FINAL SYSTEM DESIGN AND RESULTS

Measurement and transmitter circuits are included in this section, as discussed in the previous section. A schematic of the transmitter and measurement circuit is shown in Figure 9, and a receiving and monitoring block diagram is shown in Figure 10. The block schematic is produced by the electrical and electronic circuit design program Fritzing. Fritzing is an open source software application that enables designers, artists, researchers, and hobbyists to create interactive electronic devices. It allows users to record and share prototypes, educate themselves in classrooms, and design printed PCB layouts for commercial manufacturing. The user-friendly interface of Fritzing makes it easier for beginners to understand and design electronic devices. [25]



Measuring Circuit

Figure 9: The transmitter and measurement circuit block diagram.



Monitoring Circuit

Figure 10: The receiving and monitoring circuit block diagram.

A device called LoRa Radio Node Kit employs sensors to monitor and communicate data to smart homes. It collects data from sensors to detect variables, such as humidity, temperature, and switch position. After processing, the data were delivered to an LCD monitor for in-depth examination. The system verifies its operational state to ensure that the LoRa network functions and is prepared to provide data. In the event of a network outage, the device waits for or attempts to reconnect. After the board is operational, it starts sending data to a base station so that it can transfer the information to a distant user, evaluate trends, or decide what automated steps should be taken. The flowchart in Figure 11 provides a thorough overview of the monitoring and data handling processes and illustrates the methodological approach adopted by the LoRa Radio Node Kit in smart home applications.

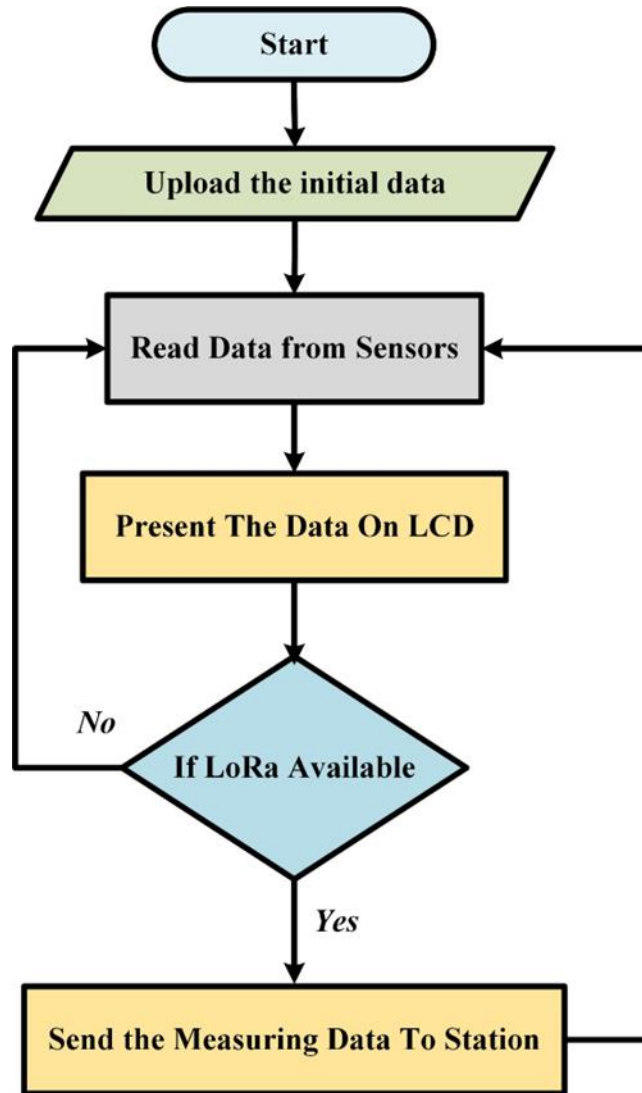


Figure 11: The measurement and transmitter circuit's flowchart.

The activation of the LoRa Radio Node Kit, which signals the start of the data-receiving process, is shown in the flowchart in Figure 12. Using LoRa communication technology, the LoRa Radio Node Kit obtains data from the transmitter circuit and displays the findings on an LCD16 × 02. The flowchart's last step shows how the processed data are displayed on an LCD display—more specifically, a 16 × 02 module, which is widely used for text display because of its ease of use and efficiency. The information is presented in an easy-to-read style on the LCD, which offers real-time updates on the state of the environment and the functionality of household appliances. With this display, customers can efficiently monitor their smart home systems and engage in real-time human interpretation and engagement.

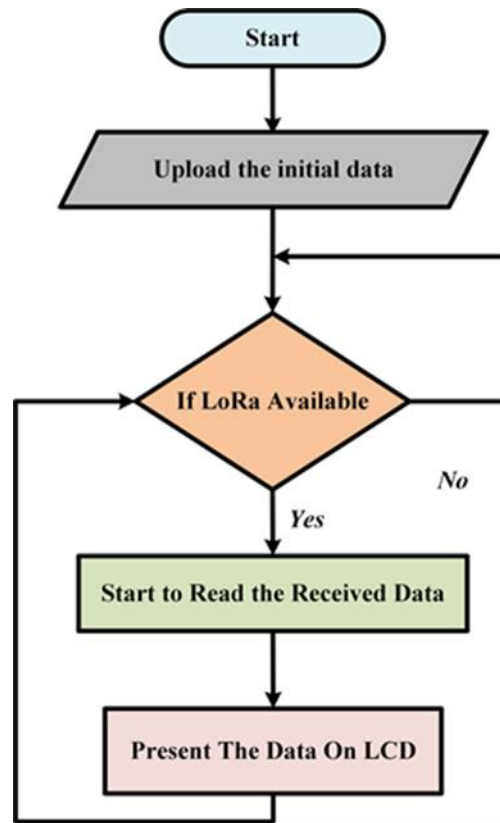


Figure 12: The measurement and transmitter circuit's flowchart.

In conclusion, all the electronic parts of the overall design of the transmitter circuit (as shown in Figure 13) and receiving circuit (as shown in Figure 14) are shown in the previous section. These include the main parts of the proposed system for monitoring a smart home using sensors and a LoRa module.

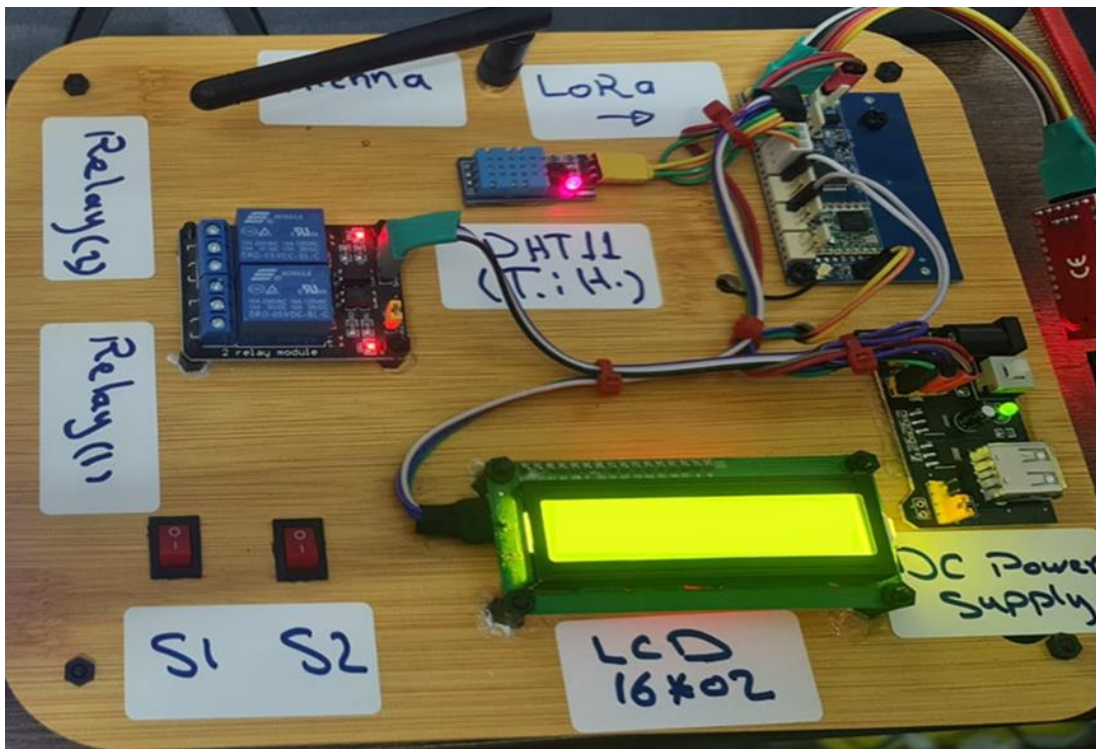


Figure 13: The complete hardware transmitter circuit with sensors and kits for LoRa radio nodes.

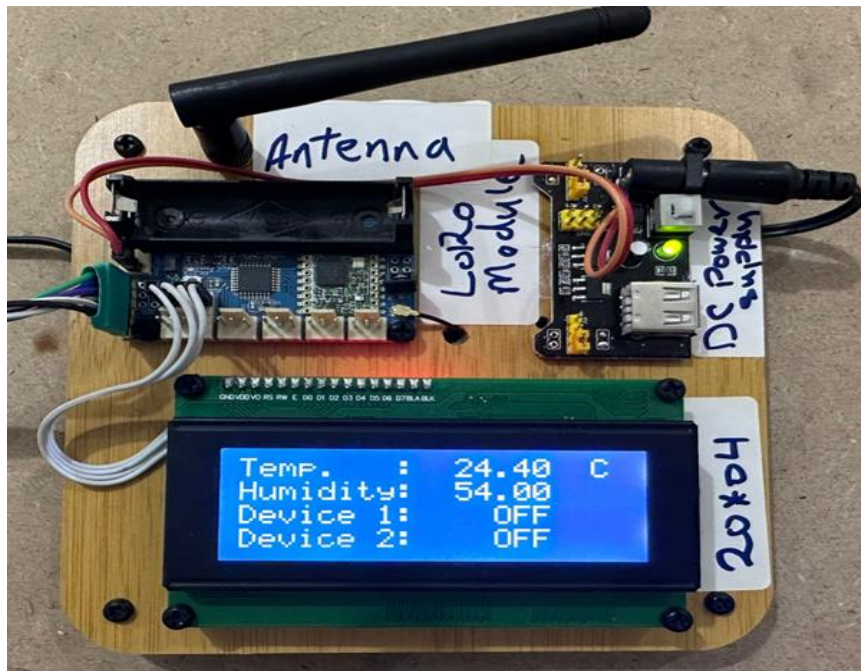


Figure 14: The complete hardware receiving circuit with an LCD and a LoRa radio node kit.

After the measuring circuit was used, a series of measurements were taken all day at one location. Figure 15 shows the results for the transmitter and receiver circuits.

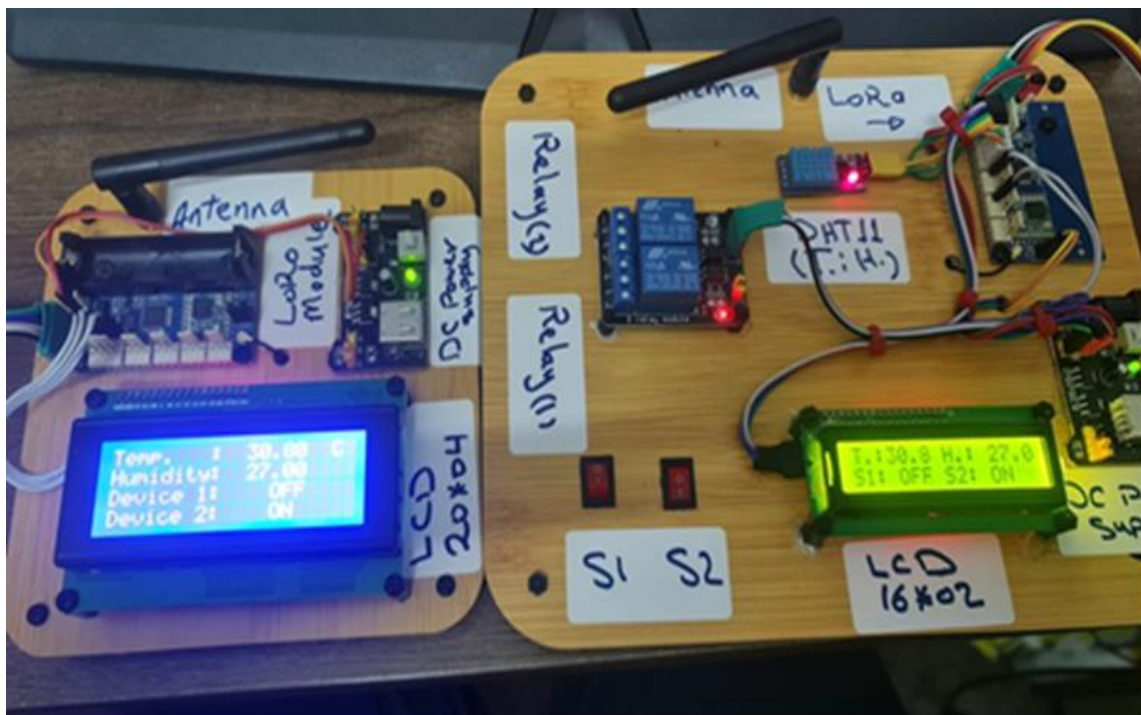


Figure 15: Set of results in the sending and receiving circuit

V. CONCLUSION

Finally, this study has shown that using LoRa technology in the design and implementation of an advanced electronic circuit for smart home uses is both possible and effective. The devised system leverages a microprocessor to interpret data from various sensors and effectively monitor environmental conditions such as temperature and humidity, as well as the operational status of home appliances. LoRa's long-range capabilities and low power consumption make it an excellent choice for wireless communications, especially in big residential environments.

The system's seamless integration with a single hub for home automation offers homeowners the convenience of remote monitoring and sophisticated data analysis. In addition to providing users with real-time data, this connection allows for automatic control to improve a home's occupant comfort and energy efficiency. The resultant smart house solution is a step toward fulfilling the larger goal of smart, sustainable living spaces, as well as a testimony to the adaptability and promise of LoRa technology in residential surroundings. The practical implications of this research could pave the way for the widespread adoption of smart home technologies, driving innovation in residential energy conservation and home management practices.

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