FACULTY OF ELECTRONIC AND COMPUTER TECHNOLOGY AND ENGINEERING

Development Of Humidity Monitoring System for Data Control Room Using Arduino

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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Bachelor of Electronics Engineering Technology (Telecommunications) with Honours

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Development Of Humidity Monitoring System for Data Control Room Using Arduino

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A project report submitted
in partial fulfillment of the requirements for the degree of
Bachelor of Electronics Engineering Technology (Telecommunications) with Honours

Faculty Of Electronic And Computer Technology And Engineering

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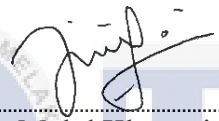
Signature : 

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DEDICATION

To my beloved mother, AISHA U.F ABDULLAHI, and father, MUHAMMAD JIBRIL, who rooted in me the value of faith, family, and supporting others while raising me according to Islamic principles. Your love and guidance light my path to my exquisite sisters, FATIMA AND KHADIJA MUHAMMAD JIBRIL, HALEEMA NURA, FATIMA, MARYAM M BUHARI and FATIMA M NASIR I am captivated every day by your unwavering support our bond is unbreakable. May Almighty reward our Sisterhood. My admission in Universiti Teknikal Malaysia Melaka was possible through my mother JAMILA M ABDULLAHI, BELLO MAGAJI, SADIQ SALISU and NURADEEN SHANONO. The sincere prayers offered by my grandmother YAHANASU ILIYASU, Aunties MARYAM(Ya Jummai),RABI, SAADATU, ZULFATU, KHADIJA(Khala),AMINA, ASIYA M ABDULLAHI and many others. My father Uncle MUHAMMAD NURA SAID,SHAMSUDEEN,JAMIL,ABDULKARIM,NURA,AMINU, SANI and many more.. I extend profound gratitude to the entire family of Professor SALIHU INGAWA, especially grandma FATIMA, mama HADIZA and AISHA. My Malaysian family/guidance, which was rooted through my aunty AISHA M JUNGODO, ABDULRAHAM PANTAMI, ZAHIRA, HALEEMA, Dr. HASSANA MANGA, and Dr. HADIZA BABBO. provided invaluable support, fostering a sense of home away from home in Nigeria. Special appreciation is reserved for Grandpa Engr. ABDULHAMID, HADIZA LAMIDO,HADIZA ABDULLAH and may others thank you all. I am extremely grateful of all of your love, guidance, and dua, my entire family mention by name or not mention by name you are all equally important to me. You give me the willpower to go after my goals. This achievement would not be possible without you, With the utmost gratitude and affection.

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ABSTRACT

This research focuses on creating a humidity monitoring system for a data control room using Arduino. The problem statement highlights the requirement for humidity control in order to prevent equipment failure and data loss. The project entails using an Arduino microcontroller board and a humidity sensor to continuously monitor humidity levels in real-time. The goal is to develop a monitoring system that is both cost-effective and reliable. The process includes connecting the humidity sensor to the Arduino board, programming the microcontroller, and building a graphical user interface for the monitoring unit. The anticipated conclusion is a cost-effective and customizable solution for successfully managing humidity levels in data control rooms.

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ABSTRAK

Penyelidikan ini memberi tumpuan kepada mencipta sistem pemantauan kelembapan untuk bilik kawalan data menggunakan Arduino. Pernyataan masalah menyerlahkan keperluan untuk kawalan kelembapan untuk mengelakkan kegagalan peralatan dan kehilangan data. Projek ini memerlukan penggunaan papan mikropengawal Arduino dan sensor kelembapan untuck memantau tahap kelembapan secara berterusan dalam masa nyata. Matlamatnya adalah untuk membangunkan sistem pemantauan yang kos efektif dan boleh dipercayai. Proses ini termasuk menyambungkan sensor kelembapan ke papan Arduino, pengaturcaraan mikropengawal, dan membina antara muka pengguna grafik untuk unit pemantauan. Kesimpulan yang dijangkakan ialah penyelesaian yang kos efektif dan boleh disesuaikan untuk berjaya menguruskan tahap kelembapan dalam bilik kawalan data.

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LIST OF ABBREVIATIONS

IDE	-	Integrated Development Environment
AI	-	Artificial Intelligence
LCD	-	Liquid Crystal Dispaly
IVS	-	Integration of Visual Studio
PID	-	Proportional-integral-derivative
$HVAC$	-	Heating, ventilation, and air conditioning
MPC	-	Model Predictive control
IoT	-	Internet of Things
DHT	-	Digital Humidity and Temperature Sensor
GUI	-	Graphical User Interface
LED	-	Light Emitting Diode
GND	-	Ground
CSV		Comma-Separated Values
ADC	-	Analogy-to-digital converter

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CHAPTER 1

INTRODUCTION

1.1 Introduction

This introduction will highlight the significance of humidity control and monitoring in data control rooms, emphasizing the importance of a humidity monitoring system as a crucial tool for maintaining optimal conditions [1].

Controlling humidity in a data control room is essential for maintaining the reliability and longevity of critical equipment. A humidity monitoring system, built using an Arduino microcontroller and a suitable sensor, provides an effective and affordable solution for continuous monitoring of humidity levels. By implementing such a system and ensuring its proper installation and maintenance, data centre operators can proactively safeguard against potential damage caused by high humidity and minimize the risks associated with equipment failures [2].

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1.2 Background

Humidity monitoring devices have already been noted, it is essential to maintain ideal humidity levels in a data control room to guarantee the efficient operation of electronic devices. Condensation can harm electronic components and result in system failures when humidity levels are high. Similarly, low humidity levels can result in a build-up of static electricity, which can harm electronic parts and cause system failures. To create and track the humidity levels in data control rooms to avert these problems. These devices can notify users when humidity levels go above a predetermined level, allowing them to take corrective action before any damage is done.

Arduino can be used to construct a humidity monitoring device by wiring a humidity sensor to the board, then programming it to examine the sensor's output and exhibit the values on an LCD screen.

Overall, utilizing Arduino to create a humidity monitoring machine provides a sensible and adaptable way to maintain the best humidity levels in records manipulate rooms while averting damage to electrical equipment [3].

1.3 Problem Statement

The possible damage to electronic equipment and health dangers caused by excessive or low humidity levels is the problem that the development of a humidity monitoring system for the data control room intends to tackle. The data control room often houses crucial electronic equipment that generates a lot of heat, and includes servers, routers, and switches. Unsatisfactory humidity control will result in a humid and extremely hot atmosphere, which could trigger numerous types of matters. Condensation can build on technological elements due to high humidity levels, creating oxidation, shorts in components, and other sorts of damage.

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This could contribute to machinery failures, data loss, and costly repairs. Low humidity, on the other hand, can cause electromagnetic radiation to gather dust, and this can harm electronic components and interfere with their efficient running. This may outcome in device errors and data loss. In addition to triggering damage to equipment, overblown or low humidity levels can create discomfort and health concerns for those working in the area, such as problems with breathing, symptoms of allergies, and cracked skin. As a result, dependable humidity monitoring system that can continually detect humidity levels in the data control room and alarm is required.

1.4 Project Objective

The main aim of this project is to propose a humidity monitoring device for a data control room to keep the degree of humidity in the room within a secure and adequate range.

- To study and identify the measuring process mechanism of the sensors and Bluetooth modules.
- To design the product using appropriate parts and components.
- To verify the functionality of the reading of the humidity sensor and communication mechanism using Bluetooth module

1.5 Scope of Project

The scope of this project are as follows:

- This expected project will culminate in the starting point is to explore the data control room's obligation to determine the sort of humidity monitoring system that would be fitting to the premises. The sq. ft. of the environment, the percentage of employees working in the work area, and the devices. assembled for the room ought to all be disclosed in the study. Following the analysis of the specifications, the humidity monitoring system is designed.
- The command unit should be positioned in a convenient location for repairs and servicing. After the system has been installed, it should be attempted to ensure that it is working soundly. as the system integration Integrated Development Environment (IDE) and Arduino-based circuit board attached along with several sensors devices and Bluetooth
- This involves guaranteeing that the sensors properly measure the degree of humidity in the room and that the command unit responses to shifts in humidity. To keep the

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system functioning at its best, it should be monitored and maintained on a constant schedule.

- Therefore, achieving a humidity monitoring system for a data control room will require a comprehensive study of requirements, competent system design, delicate installation has finished, thorough testing, and frequent upkeep and checking.

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CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This section covered the whole project's literature study and development. Primary sources for this project would include journals, papers, and books from previous works connected to the project's theme. This chapter will go through the principles as well as associated research applications. The literature review focuses on the significance of humidity control in data control rooms. It explores the impact of improper humidity levels on data center operations and discusses recommended humidity ranges for maintaining optimal conditions[4].

2.2 Humidity Control in Data Control Rooms

This section of the literature review focuses on the significance of humidity control in data control rooms. It explores the impact of improper humidity levels on data center operations and discusses recommended humidity ranges for maintaining optimal conditions [5].

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2.2.1 Significance of Humidity Control for Equipment Reliability and Performance

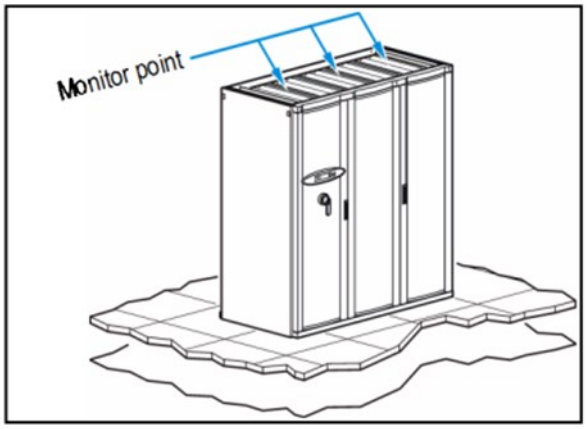

Figure 2.1 Controlling equipment.

Controlling humidity is critical for guaranteeing the durability and performance of equipment in data control rooms. High humidity levels can harm electronic components, resulting in equipment failures and downtime. Low humidity, on the other hand, can produce static electricity accumulation and raise the risk of electrostatic discharge, which can damage sensitive electronics [6].

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Excessive humidity can cause the following problems:

1. Excessive moisture can cause corrosion in metal components such connectors, circuit boards, and cooling systems. Corrosion can damage connections, produce electrical shorts, and reduce overall device performance.
2. Condensation can occur when warm, moist air comes into touch with cooler surfaces. This can cause water droplets to accumulate on equipment, resulting in short circuits and damage to sensitive electronic components.
3. Excessive humidity can damage mechanical components such as hard disc drives, causing them to malfunction or fail prematurely. The presence of moisture in the air can also cause lubricants used in mechanical systems to degrade.

2.2.2 The Effect of Inadequate Humidity Levels on Data Centre Operations

- Improper humidity levels can have a substantial impact on the overall operation of a data centre. High and low humidity levels can also cause a variety of problems, including [7]:
- Equipment failures caused by humidity-related concerns can result in costly downtime, affecting corporate operations and potentially resulting in data loss.
- High humidity can hasten the breakdown of electrical components, shortening their lifespan and forcing more frequent replacements.
- Improper humidity control can have a significant impact on data centre energy efficiency. Overcooling or overcompensating for high humidity can result in increased energy usage and greater operational expenses [8].
- Impact on the Environment: Inefficient humidity control practices can lead to increased energy usage and, as a result, higher carbon emissions. This may have a harmful impact on the environment.
- It is critical to solve humidity-related concerns in data control rooms to maintain optimal performance, dependability, and energy efficiency.

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2.2.3 Recommendations for Data Control Room Humidity Ranges

Recommended humidity ranges for data control rooms are provided by several standards and guidelines. The following are commonly accepted guidelines for humidity control in data centres[3]:

- ASHRAE (American Society of Heating, Refrigerating, and Air-Conditioning Engineers): For data centres, ASHRAE recommends a

humidity range of 40% to 60% relative humidity (RH), with a 5% RH permissible deviation.

Table 2.1 ASHRAE range for data centers [9].

	Recommended		Allowable	
Year	2004	2008	2004	2008
Temperture range	20˚C-25˚C	18˚C-27˚C	15˚C-32˚C	10˚C-35˚C
Moisture range	40%-55%RH	5.5˚C DP-60%RH	20%-80%RH	20%-80%

- ISO (International Organization for Standardization): ISO 14644-1 specifies a humidity range for data centres of 40% to 60% RH.
- These recommended values establish a balance between limiting excessive moisture and reducing the risk of electrostatic discharge.
- However, specific needs may differ depending on the type of equipment, data centre design, and geographic location of the facility. To establish the most acceptable humidity ranges for their individual settings, data centre operators should examine these parameters as well as review industry standards and manufacturer recommendations[6].
- Data control rooms can maintain ideal conditions for equipment performance, dependability, and energy savings by adhering to established humidity ranges.

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2.3 Sensing Technologies for Humidity Monitoring

The study focuses on various humidity sensing technologies used in data control rooms to monitor and control humidity levels. It gives an overview of various sensing technologies, examines their benefits and drawbacks, and emphasizes the selection criteria for humidity sensors in data control rooms[10].

2.3.1 An Overview of Humidity Sensing Technologies

For measuring humidity levels, numerous humidity sensor systems are available. Sensing technologies that are regularly utilized include [11]:

1. Capacitive Humidity Sensors: Capacitive humidity sensors detect changes in capacitance induced by moisture absorption or release. They are made up of a humidity-sensitive capacitor and a sensing element, which is often comprised of polymer or metal oxide. The change in capacitance is proportional to the level of humidity.
2. Resistive Humidity Sensors: Resistive humidity sensors use a humidity-sensitive substance that alters electrical resistance in reaction to moisture. The humidity level is then determined by measuring the change in resistance. Polymers and ceramic substrates can be used to make resistive sensors.
3. Optical Humidity Sensors: Optical sensors use optical characteristics that change with moisture absorption to measure humidity. These sensors are primarily based on light absorption or reflection by a hygroscopic substance or a detecting device that interacts with moisture.
4. Thermal Conductivity Humidity Sensors: Thermal conductivity sensors examine a material's thermal conductivity to determine its humidity level.

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Moisture influences thermal conductivity, allowing the sensor to calculate humidity using heat transfer properties.

5. Gravimetric Humidity Sensors: Gravimetric humidity sensors detect moisture by directly measuring the weight change of a moisture-absorbing substance. The weight change caused by moisture absorption or desorption is monitored and transformed into humidity readings.

2.3.2 The Benefits and Drawbacks of Each Sensing Technology

Table 2.2 Humidity detecting technology advantages and disadvantages [4], [12]:

Humidity detecting Sensors	Advantages	Disadvantages
Capacitive Sensors	They have good accuracy, quick response times, and a wide measuring range. They are also reasonably priced and appropriate for mass production.	Capacitive sensors can be contaminated by dust or chemical exposure, necessitating regular maintenance and calibration.
Resistive Sensors	Resistive sensors are relatively affordable, consume little power, and provide accurate data.	They may have slower response times and smaller measurement ranges than capacitive sensors.

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	They are also less susceptible to contamination than capacitive sensors	They can also be affected by temperature changes.
Optical Sensors	Optical sensors provide high accuracy, long-term stability, and electrical interference protection.	Optical sensors can be more expensive than other types, and the presence of impurities or humidity on the optical elements can influence their effectiveness.
	They may be used in severe settings and consume little power.	
Thermal Conductivity Sensors	They can be used to measure the thermal conductivity of gases, liquids, and solids.	They may not be suitable for measuring the thermal properties of non-conductive materials, such as plastics or ceramics, without additional modifications or techniques.
	They are suitable for a variety of materials and environments.	
Gravimetric Sensors	They have great precision and stability.	They are generally more complex, expensive, and not as commonly used as other sensing technologies.
	They can provide traceable humidity readings and be used for calibration.	They may also respond more slowly.

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2.3.3 Humidity Sensor Selection Criteria in Data Control Rooms

Several criteria should be addressed while selecting humidity sensors for data control rooms [13]:

- Accuracy and precision: Within the desired humidity range, the sensor should deliver accurate and exact data.
- Response Time: The sensor's response time should be rapid enough to detect changes in humidity quickly.
- Stability: The sensor's calibration and performance should remain stable over time with no substantial drift.
- Reliability: The sensor should be dependable and last a long time.
- Environmental Compatibility: The sensor should be suitable for the data center environment, including temperature variations, dust, and potential contaminants.
- Calibration and Maintenance: The calibration and maintenance requirements of the sensor should be considered.
- Cost: The cost of the sensor, as well as its compatibility with the total budget, should be considered.
- Industry Standards: The sensor should comply with relevant industry standards and humidity measuring guidelines.

By taking these factors into account, data center operators may make informed decisions when purchasing humidity sensors to ensure accurate and dependable humidity monitoring in their facilities [13].

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2.4 Data Analysis Techniques

Data analysis techniques used in humidity monitoring systems. It introduces these methodologies, examines statistical analysis for humidity data, and investigates machine learning and artificial intelligence approaches for anomaly detection and prediction [14]

2.4.1 Introduction to Data Analysis Techniques Used in Humidity Monitoring Systems

Data analysis techniques are used to make sense of the obtained humidity data and derive valuable insights. These strategies aid in discovering patterns, trends, anomalies, and correlations in data. Some popular data analysis techniques used in humidity monitoring systems include [15]:

1. Statistical Analysis: Statistical techniques are used to analyses humidity data, produce descriptive statistics, and uncover patterns and relationships within the data.
2. Time-Series Analysis: Time-series analysis focuses on analysing data collected over time to detect patterns, seasonality, and trends. It aids in understanding the temporal behaviour of humidity levels and finding anomalies.
3. Data Visualization: Data visualization techniques are used to visually portray humidity data, enabling easier understanding and discovery of patterns or outliers.
4. Machine Learning and Artificial Intelligence: Advanced approaches such as machine learning and artificial intelligence algorithms are used for anomaly detection, prediction, and decision-making based on historical humidity data.

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2.4.2 Statistical Analysis of Humidity Data

Understanding and interpreting humidity data relies heavily on statistical analysis. The following are some common statistical techniques for analysing humidity data [8]:

1. Descriptive Statistics: Descriptive statistics give summary measurements such as mean, median, standard deviation, and percentiles to explain the central tendency, dispersion, and shape of the humidity data.
2. Hypothesis Testing: Hypothesis testing determines whether there are significant differences or correlations between humidity levels under different settings or scenarios.
3. Correlation Analysis: Correlation analysis evaluates the link between humidity levels and other variables such as temperature or equipment performance to find potential dependencies.
4. Regression Analysis: Regression analysis aids in modelling the link between humidity and other variables, allowing predictions and understanding the impact of various factors on humidity levels.

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2.4.3 Machine Learning and Artificial Intelligence Anomaly Detection and Prediction Methodologies

Machine learning and artificial intelligence (AI) techniques have gained popularity in humidity monitoring systems for anomaly identification and prediction. These approaches involve training algorithms using past humidity data to learn patterns and generate predictions. Some common strategies are [4]:

1. Anomaly Detection: Machine learning algorithms can detect aberrant or anomalous humidity data that differ significantly from predicted trends. For

anomaly identification, many techniques like clustering, classification, and time-series analysis can be used.

2. Predictive Modelling: Machine learning models such as regression, time series forecasting, and neural networks can be taught to predict future humidity levels based on historical data. These models can aid in the proactive monitoring and maintenance of humidity control systems.
3. Decision Support Systems: AI approaches like expert systems and rule-based systems can be used to give decision support for humidity management. These systems can create recommendations or alerts based on real-time data analysis.

These advanced data analysis techniques improve understanding of humidity data, enable proactive interventions, and optimize humidity control in data control rooms.

2.5 Control Strategies for Humidity Management

This section of the literature review focuses on control mechanisms used to maintain ideal humidity levels in data control rooms. It discusses feedback control systems and proportional-integral-derivative (PID) controllers, as well as adaptive control methods for real-time humidity adjustment [16].

2.5.1 Overview of Control Strategies for Maintaining Optimal Humidity Levels

In data control rooms, numerous control mechanisms are used to maintain ideal humidity levels. These strategies include [17] :

1. Humidification Systems: Humidification systems infuse moisture into the air to raise humidity levels when they fall below the appropriate range.

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2. Dehumidification Systems: Dehumidification systems remove excess moisture from the air to reduce humidity levels when they exceed the recommended range.
3. HVAC Systems: Heating, ventilation, and air conditioning (HVAC) systems are critical in controlling humidity levels. They regulate temperature and humidity by conditioning the air before it is circulated in the data control room.
4. Airflow Management: Proper airflow management, including the use of containment systems and strategic positioning of air vents, aids in the maintenance of uniform humidity distribution throughout the facility.

2.5.2 Feedback Control Systems with Proportional-Integral-Derivative (PID) Controllers

Feedback control systems are often used to adjust humidity levels in data control rooms. These systems continuously monitor humidity levels and alter the humidification or dehumidification procedures accordingly. PID controllers are extensively employed in feedback control systems and provide a control algorithm that changes the output based on the difference between the planned humidity setpoint and the actual humidity reading [18].

To calculate the control signal that changes the operation of the humidification or dehumidification system, the PID controller considers the proportional, integral, and derivative components. The proportional component responds to the current error, the integral component examines the cumulative past errors, and the derivative component predicts future errors based on the error's rate of change.

PID controllers in humidity control systems strike a compromise between stability, responsiveness, and steady-state accuracy [1].

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2.5.3 Adaptive Control Algorithms for Real-Time Humidity Regulation

For real-time humidity regulation in dynamic situations, adaptive control methods are used. These algorithms continuously alter the control parameters based on the current operating conditions, considering elements like airflow, temperature, occupancy, and external environmental conditions [19].

Adaptive control algorithms use sensor feedback and previous data to adaptively optimize the control approach. These algorithms can automatically modify setpoints, control settings, or switching thresholds to maintain appropriate humidity levels in response to changing conditions.

These algorithms, which might be based on approaches such as model predictive control (MPC), fuzzy logic control, or neural networks, enable dynamic and proactive humidity management in data control rooms. Data control rooms can successfully regulate humidity levels by using proper control techniques and feedback control systems or adaptive control algorithms [6].

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2.6 Case Studies and Research Findings

The review focuses on case studies and research publications about humidity monitoring systems for data control rooms. It entails reviewing the results of these investigations, assessing the systems' performance and efficacy in regulating humidity levels, and identifying difficulties and potential areas for improvement[11].

2.6.1 Review of Relevant Studies and Research Articles on Data Control Room Humidity Monitoring Systems

A survey of pertinent papers and research publications gives useful information about the design, installation, and performance of humidity monitoring systems in data

control rooms. Experiment assessments, comparison analyses, and case studies undertaken in real-world data center environments are examples of these studies.

The purpose of this review is to gather information on the various approaches, methodologies, and technology used in humidity monitoring systems. It investigates the effect of humidity regulation on the reliability of equipment, energy efficiency, and overall data center operations [11].

2.6.2 System Performance and Effectiveness in Maintaining Humidity Levels Evaluation

The efficiency of humidity monitoring systems in maintaining ideal humidity levels within data control rooms is examined during system performance review. It evaluates the sensors' accuracy and reliability, the responsiveness of the control mechanisms, and the overall stability of the humidity control system [20].

The study also includes the effect of humidity control on equipment performance and dependability. It investigates any relationships that may exist between humidity levels, device failures, and energy consumption. These evaluations aid in assessing the effectiveness of the established systems and their impact on data center operations.

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2.6.3 Identifying Challenges and Potential Improvement Areas

It is critical to identify difficulties and potential areas for development when improving humidity monitoring systems in data control rooms. Identifying technical, operational, and implementation difficulties encountered during system deployment is part of this process. Sensor calibration difficulties, data accuracy and dependability, system maintenance, and interaction with existing infrastructure are all common challenges.

Identifying possible areas for improvement also includes investigating new technologies, processes, or best practices that can address identified difficulties and optimize

humidity control in data control rooms. Sensor technologies, control algorithms, data analysis techniques, and overall system design and integration may be the focus of these enhancements [21].

2.7 Future Directions and Challenges

1. Identifying Gaps in Existing Humidity Monitoring Systems

Identifying gaps in present humidity monitoring systems aids in evaluating limitations and possibilities for development. These shortcomings may include a lack of standardized humidity management methods, insufficient monitoring capabilities, poor integration with other environmental control systems, or limited scalability in large data centers. Recognizing these gaps helps to guide future research and development activities [3].

2. Research Potential an Emerging Technologies

Future research in humidity monitoring systems for data control rooms may include investigating advanced sensor technologies with higher accuracy and reliability, developing predictive analytics models for proactive humidity control, researching the impact of humidity on emerging technologies (e.g., edge computing, AI infrastructure), and integrating humidity control with energy efficiency strategies [5], [9].

Furthermore, emerging technologies such as the Internet of Things (IoT), edge computing, and artificial intelligence have the potential to improve humidity monitoring and control systems. Innovative ways for real-time monitoring, adaptive control, and intelligent decision-making can be gained through research in these fields.

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3. Difficulties in Installing Humidity Control Systems in Existing Data Control Rooms

Because of the complexity and criticality of data center operations, implementing humidity control systems in existing data control rooms can be difficult. Infrastructure retrofitting, integration with legacy systems, minimizing disturbances during installation, and guaranteeing compatibility with current control systems may all be challenges [6]. Furthermore, issues of cost-effectiveness, scalability, and the dynamic nature of data center infrastructures must be addressed. Understanding and overcoming these obstacles is critical for the successful implementation and operation of humidity control systems in existing data control rooms.

Future paths in humidity monitoring systems for data control rooms can be formed by identifying gaps, researching possible research topics, and addressing implementation issues, leading the way for increased performance, energy efficiency, and dependability of these essential environments.

The literature study, providing a thorough summary of relevant studies and research articles on humidity monitoring systems for data control rooms. It examines system performance, identifies obstacles and potential areas for improvement, and defines future directions and challenges in this discipline [8], [14].

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2.8 Energy Efficiency and Sustainability

In humidity monitoring systems for data control rooms, energy economy and sustainability are critical issues. Maintaining proper humidity levels not only assures the durability of equipment, but it also adds to energy efficiency and sustainability efforts. Data centers can get the following benefits by keeping humidity within the acceptable ranges [12], [21]:

1. Energy Savings: Proper humidity control minimizes the energy consumption of humidification and dehumidification systems, resulting in lower operational costs and an influence on the environment.
2. Equipment Efficiency: Keeping humidity levels adequate enhances the efficiency and performance of IT equipment, decreasing energy waste and extending the life of hardware components.
3. Cooling Efficiency: Controlling humidity levels aids in the optimization of HVAC system cooling efficiency, resulting in lower energy usage for temperature management.
4. Environmental Impact: Data centers can reduce their carbon footprint and contribute to overall sustainability goals by deploying effective humidity monitoring and control systems.

In order to connect data center operations with environmentally conscious practices and reduce the industry's total ecological impact, humidity monitoring systems must include energy efficiency and sustainability[12].

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2.9 Journal Comparison from Previous Work Related to the Project

Table 2.3 Journal Comparison from Previous Work Related to the Project

Journal	Title	Author	Finding	Years	Techniques	Advantages	Disadvantages
Journal 1	System of wireless temperature and humidity monitoring	Y. Wang and Z. Chi	Focuses on the design and implementation of a wireless humidity monitoring system for data control rooms with Arduino.	2016	Wireless temperature sensor, wireless humidity sensor	Flexible placement and easy installation due to wireless nature. Real-time monitoring without the need for wired connections. Remote accessibility and monitoring capabilities.	Requires additional infrastructure for wireless connectivity (e.g., gateways, receivers). Reliability and range limitations of wireless communication. Potential interference or security concerns with wireless signals.
Journal 2	Design of temperature and humidity intelligent monitoring system	W. Z. Zhang, S. Q. Ma, M. H. Fan, and J. L. Li	Integration of Arduino-based humidity monitoring system with industrial	2010	Temperature sensor, humidity sensor	Accurate measurement and monitoring of temperature and humidity levels. Intelligent monitoring capabilities for data analysis and decision-making. Potential for	Requires additional components for data processing and analysis. Limited computational capabilities of the monitoring system. Calibration and periodic maintenance of sensors.

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			automation platform			integration with other systems or devices.	
Journal 3	Design and Implementation of Temperature and Humidity Monitoring System Using LPWAN Technology	M. S. Danladi and M. Bay kara	Focuses on the development and performance evaluation of an Arduino-based humidity monitoring system designed specifically for data control rooms.	2022	LPWAN Technology (Low Power Wide Area Network) sensors	LPWAN networks can support a large number of connected devices, making it easy to scale up the monitoring system as needed without significant infrastructure modifications	LPWAN technology may have limitations in terms of customization and flexibility compared to other wireless communication options. This may restrict the ability to incorporate additional sensors or features into the monitoring system based on specific requirements.
Journal 4	Designing a Data Centre Environmental Monitoring Solution	Bill Kleyman	Environmental assessment of humidity levels in data control rooms	2019	Temperature sensor, humidity sensor, data logging system	Monitoring and control of temperature and humidity in data centers for optimal performance. Early detection of environmental anomalies that may affect equipment reliability. Integration with	Complex setup and configuration process. Cost of additional components and infrastructure. Maintenance and calibration requirements.

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						existing data center infrastructure.	
Journal 5	Design and implementation of intelligent temperature and humidity monitoring system based on ZigBee and WiFi	J. Xiao and J. T. Li	Wireless Arduino-based humidity monitoring system with cloud connectivity	2020		Wi-Fi technology offers broad coverage, allowing for monitoring in larger areas or multiple rooms, while ZigBee provides a low-power and short-range option for localized monitoring within a network.	Wi-Fi communication typically consumes more power compared to ZigBee, which may impact the battery life of wireless sensors or devices. Efficient power management should be considered to maximize battery lifespan.
Journal 6	Design and Implementation of Temperature and Humidity Monitoring System Using LPWAN Technology	M. S. Danladi and M. Baykara	Predictive control strategy for humidity regulation	2022	LPWAN Technology temperature sensor, humidity sensor	Long-range communication and low power consumption with LPWAN technology. Accurate monitoring of temperature and humidity conditions. Remote monitoring capabilities in areas with limited connectivity.	Coverage limitations of LPWAN networks in certain regions. Initial setup and configuration complexity. Potentially higher cost compared to other monitoring solutions.

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Journal 7	Humidity and Temperature Monitoring using Arduino with ESP8266	randomnerdtutorials.com	Enhanced sensitivity and selectivity sensors for humidity monitoring		Arduino with ESP8266 module, temperature sensor, humidity sensor	Cost-effective and widely available Arduino platform. ESP8266 enables wireless connectivity and remote monitoring capabilities. Accurate measurement and monitoring of temperature and humidity.	Limited computational capabilities of Arduino board. Complexity in configuring and programming the ESP8266 module. May require additional components for data visualization or integration.
Journal 8	Indoor environment monitoring based on humidity conditions	L. Barik	Presents the development of a low-cost humidity monitoring system using Arduino for data control rooms.	2019	Humidity Sensor Temperature Sensor Display (LCD, OLED	By monitoring humidity levels, the system can help prevent the growth of mold, mildew, and moisture-related issues that can lead to property damage and potential health hazards	Proper sensor placement is crucial for accurate humidity measurements. Obstructions or incorrect positioning may affect the readings, requiring careful consideration during system setup.
Journal 9	Concrete temperature monitoring using passive wireless surface	J. Kim, R. Luis, M. S. Smith, J. A. Figueroa, D. C.	using passive wireless surface acoustic wave sensor system	2015	Passive wireless surface acoustic wave sensor system	Non-intrusive and wireless monitoring of concrete temperature. Passive sensors do not require a power source or wiring. Real-time	Limited range of SAW sensors. Sensitivity to environmental factors that may affect sensor accuracy. May require specialized equipment for sensor installation and data retrieval.

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	acoustic wave sensor system	Malocha, and B. H. Nam				monitoring for early detection of temperature variations.	
Journal 10	Design of Monitoring System Temperature And Humidity Using DHT22 Sensor and NRF24L01 Based on Arduino	Azhari, T. I. Nasution, S. H. Sinaga, and Sudiati		2023	DHT22 Sensor and NRF24L01	Affordable and accessible Arduino platform. DHT22 sensor provides accurate temperature and humidity measurement. NRF24L01 enables wireless communication between nodes.	Limited range and reliability of NRF24L01 module. Complexity in configuring and programming NRF24L01 communication. Potential power consumption concerns for long-term monitoring.
Journal 11	Embedded smart sensor dipole antennas for real-time damage assessment, humidity, and temperature	M. Ozturk	Discusses an Arduino-based humidity monitoring system designed to manage data control rooms in an energy-efficient manner.	2022	Embedded Smart sensor dipole antennas	Real-time monitoring of structural damage, humidity, and temperature. Embedded sensors provide continuous data collection without interfering with the structure. Early detection of potential	Complex installation process and integration with the concrete structure. Calibration and periodic maintenance of embedded sensors. Requires specialized equipment and expertise for installation and data retrieval.

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	monitoring in reinforced and non-reinforced concrete structures					structural issues for maintenance or repair.	
Journal 12	System of wireless temperature and humidity monitoring	Y. Wang and Z. Chi	Focuses on the design and implementation of a wireless humidity monitoring system for data control rooms with Arduino	2022	Arduino Uno platform Wireless temperature sensor, wireless humidity sensor	Flexible placement and easy installation due to wireless nature. Real-time monitoring without the need for wired connections. Remote accessibility and monitoring capabilities.	Requires additional infrastructure for wireless connectivity (e.g., gateways, receivers). Reliability and range limitations of wireless communication. Potential interference or security concerns with wireless signals.
Journal 13	Indoor environment monitoring based on humidity conditions	O. Bamodu, F. Osebor, L. Xia, A. Cheshmehzangi, and L. Tang		2016	Low-cost sensor network	Accurate measurement and monitoring of indoor humidity conditions. Enables assessment of indoor air quality and comfort. Potential integration with HVAC systems for automated control.	Limited scope of monitoring compared to comprehensive environmental monitoring systems. May require additional sensors for comprehensive indoor environment monitoring. Calibration and maintenance requirements for humidity sensors.

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Journal 14	Design and development of Arduino based portable air quality monitoring systems	S. Vishwas et al.	based portable air quality monitoring	2018	Arduino-based portable air quality monitoring systems	The design of Arduino-based systems allows for their portability, enabling users to monitor air quality in various locations and environments. Arduino-based systems often come with user-friendly interfaces and software, making it easier for users to set up, monitor, and interpret air quality data	Arduino-based systems rely on batteries or external power sources, which can limit the operational time and continuous monitoring capability, especially in remote or inaccessible locations.
Journal 15	Design and Implementation of Temperature and Humidity Intelligent Monitoring System	IEEE Conference Publication	Discusses an Arduino-based humidity monitoring system designed to manage data control rooms in an energy-efficient manner.	N/A	Temperature sensor, humidity sensor	Accurate measurement and monitoring of temperature and humidity. Intelligent monitoring system for data analysis and decision-making. Potential for integration with other systems or devices.	Requires additional components for data processing and analysis. Limited computational capabilities of the monitoring system. Calibration and periodic maintenance of sensors.
Journal 16	Make a Hygrometer to	J. Watson et al.,	Impact of humidity variations on	N/A	humidity monitoring	Simple and affordable solution for measuring	Limited accuracy compared to professional-grade sensors. May

	Measure Humidity		electronic equipment performance and reliability		system Hygrometer sensor	humidity. DIY project for educational purposes or personal use. Provides basic understanding of humidity measurement principles.	require manual calibration for improved accuracy. DIY project may lack advanced features or capabilities.
Journal 17	Temperature and Humidity Sensor Using Arduino	Sohel Datta Yugandhara	Performance assessment of Arduino-based humidity monitoring system	2016	Arduino-based humidity monitoring system	Cost-effective and widely available Arduino platform. Accurate measurement and monitoring of temperature and humidity. Flexible integration with other Arduino-compatible devices or systems.	Limited computational capabilities of Arduino board. May require additional components for data visualization or integration. Calibration and maintenance requirements for temperature and humidity sensors.
Journal 18	Humidity Monitoring System Using LPWAN Technology	Revati M. Wahul		2022	LPWAN module, humidity sensor	Long-range communication and low power consumption with LPWAN technology. Accurate monitoring of humidity conditions. Remote monitoring capabilities in areas with limited connectivity.	Coverage limitations of LPWAN networks in certain regions. Initial setup and configuration complexity. Potentially higher cost compared to other monitoring solutions.

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Journal 19	Design and implementation of temperature and humidity monitoring system for small cold storage of fruit and vegetable based on Arduino	X. Tang, C. Tan, A. Chen, Z. Li, and R. Shuai	implementation of temperature and humidity monitoring system for small cold storage	2020	Arduino	The system can provide accurate measurements of temperature and humidity levels, ensuring optimal storage conditions for fruits and vegetables, which helps to extend their shelf life and maintain quality.	Arduino boards may have limited connectivity options, which can impact the system's ability to transmit data in real-time or integrate with other networked devices or data management systems.
Journal 20	Arduino-Based Weather Monitoring System	www.researchgate.net/publication/330220305	Focuses on the design and implementation of weather, humidity monitoring system with Arduino	2020	Arduino-based humidity monitoring system weather sensors (temperature, humidity)	Cost-effective and user-friendly Arduino platform. Weather sensors enable accurate monitoring of temperature and humidity. Flexibility to add additional sensors for comprehensive weather monitoring.	Limited computational capabilities of Arduino board. May require additional components for data visualization or integration. Calibration and maintenance requirements for weather sensors.

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2.10 Summary

Finally, the literature study gives useful information about humidity monitoring systems for data control rooms. The following are some of the review's key findings [22]:

- Maintaining equipment dependability and performance in data control rooms requires humidity control. Humidity levels that are too high can cause device failure, data loss, and operational disturbances.
- Different humidity detection methods, including capacitive, resistive, and optical sensors, have advantages and disadvantages in terms of accuracy, dependability, and cost.
- Statistical analytic methods, machine learning, and artificial intelligence technologies are critical in analyzing humidity data, detecting abnormalities, and forecasting future humidity levels.
- To regulate humidity levels in data control rooms, control strategies such as feedback control systems with PID controllers and adaptive control algorithms are used.
- Case studies and research articles provide insights into system performance, problems, and potential areas for development in data control room humidity monitoring systems.

Humidity monitoring systems in data control rooms are quite important. Maintaining proper humidity levels ensures that equipment is reliable and performs well, reducing the risk of data loss and operational disruptions. Furthermore, good humidity control adds to data center energy efficiency, sustainability, and overall environmental responsibility[16].

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Humidity monitoring systems can improve the dependability, energy efficiency, and sustainability of data control rooms by addressing these research areas and implementing recommended enhancements.

This chapter finishes the literature study by summarizing the important findings, emphasizing the significance of humidity monitoring systems, and making recommendations for future research and improvements.

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CHAPTER 3

METHODOLOGY

3.1 Introduction

Arduino will be used in the project to create a humidity monitoring system for a data control room. For sensitive electronic equipment to operate properly and to last as long as possible in a data control room, ideal humidity levels must be maintained. While insufficient humidity can lead to the accumulation of static electricity and hinder the operation of machinery, high humidity can result in corrosion, condensation, and damage to electronic components. The installation of a reliable and accurate humidity monitoring system is essential to ensure the proper operating conditions in the control room. One of the project's objectives is the design of a system that can accurately measure and track humidity levels in real-time. The crew in the control room will be able to promptly see any departures from the appropriate humidity range and take the necessary safety measures to prevent potential equipment damage. The device will also offer a user-friendly interface to display the humidity levels for simple data analysis and monitoring.

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3.2 Methodology

This thesis methodology explains the step-by-step procedure for creating an Arduino-based humidity monitoring system for a data control room The system's goal is to offer actual humidity monitoring and management in the control room setting, assuring perfect conditions for data storage and equipment functioning. The procedure includes the development of hardware and software as well as the incorporation of sensors, data gathering, and system testing.

3.2.1 Project planning

Project flowchart

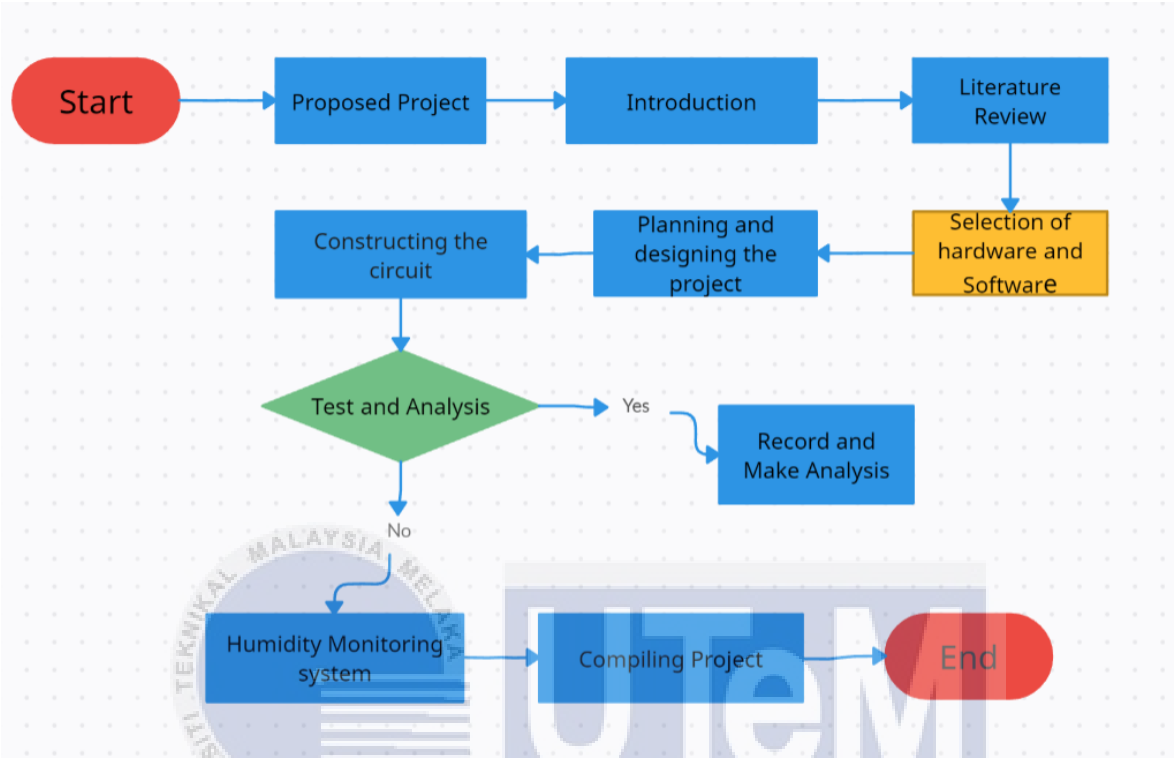

Figure 3.1: Project flow chart

3.2.2 System Desigins

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To detect and track humidity levels in the data control room, a number of interconnected components make up the overall system architecture for the humidity monitoring system.

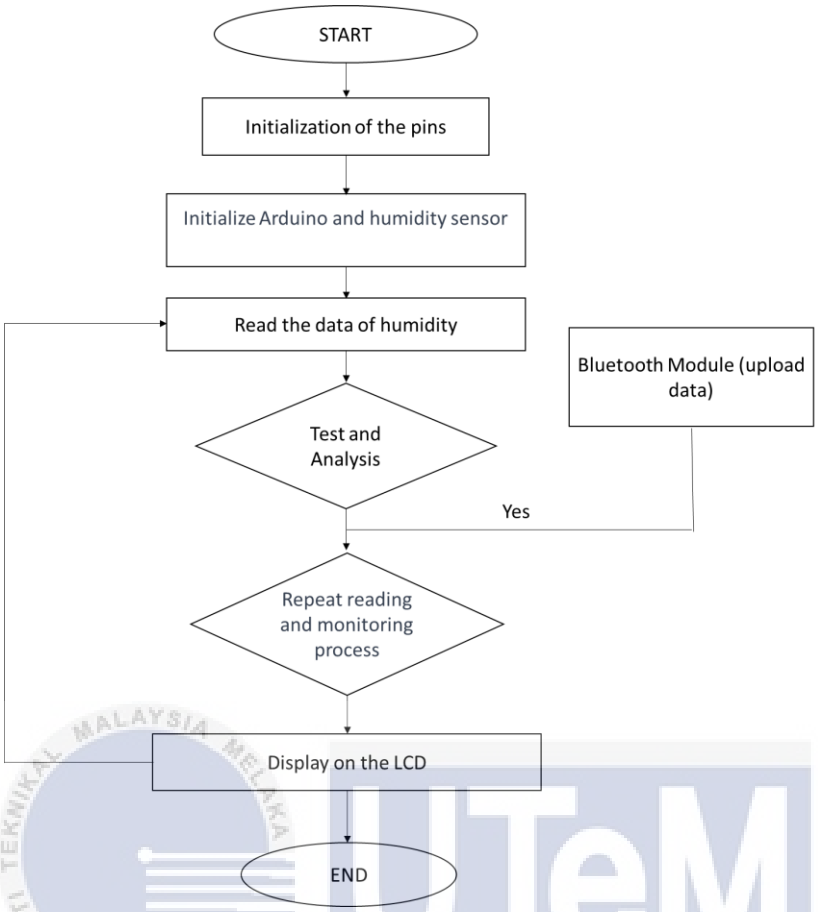

Figure 3.2: System flow chart

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3.2.3 Components

3.2.3.1 Arduino Board

The system's central controller is the Arduino board. It gathers information from the humidity sensor, analyses it, and manages the display unit.

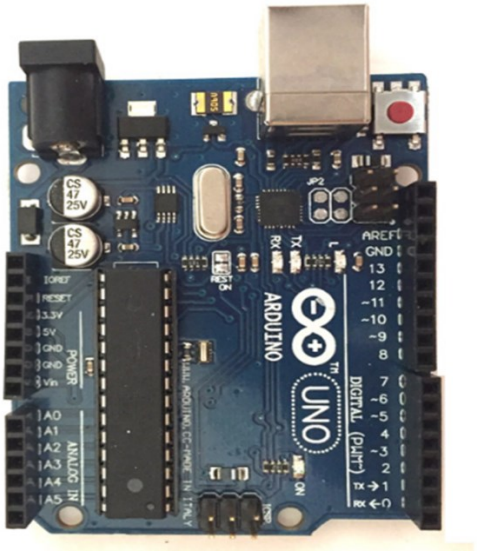

Figure 3.3 Arduino Board

3.2.3.2 Humidity and Temperature Sensor

To gauge the humidity levels in the control room, a top-notch humidity sensor, such as the DHT series or the SHT series, is utilised. Within a given range, the sensor offers precise measurements.

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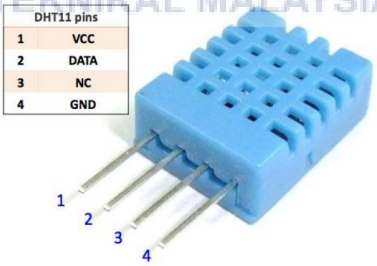

Figure 3.4 Humidity Sensor

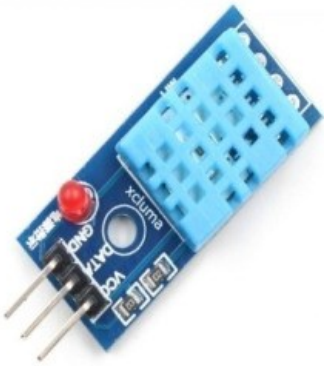

Figure 3.5 Temperature Sensor

Here are the ranges and accuracy of the DHT11:

- Humidity Range: 20-90% RH
- Humidity Accuracy: ±5% RH
- Temperature Range: 0-50 °C
- Temperature Accuracy: ±2% °C

$RH = \rho w\ \rho s \times 100\%$,

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3.2.3.3 Display Unit

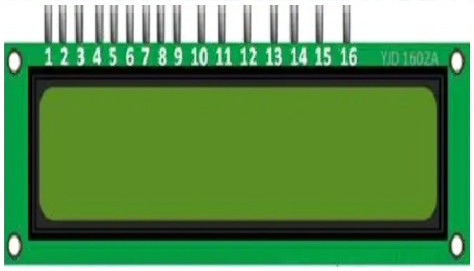

Figure 3.6 Display unit

An LCD or OLED display is attached to the Arduino board as a display unit. The user can see the current humidity readings.

3.2.3.4 Bluetooth Module

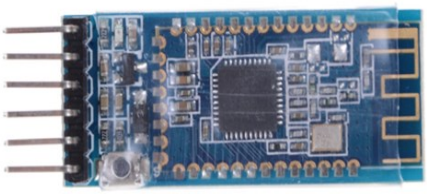

Figure 3.7 Bluetooth Module

Bluetooth Module Upload data to the base station / laptop (GUI) are frequently employed to provide auditory alarms or notifications in a variety of applications, for example, can be used in a humidity monitoring system for a data control room to notify when humidity levels reach a given threshold, alerting workers to take appropriate action.

3.2.3.5 Power source

Figure 3.8 Power source

For the system to function consistently, it needs a reliable power source. Depending on the installation needs, either a battery or a wall converter can provide this.

- The proper wiring connections are used to join the humidity sensor to the Arduino board. Depending on the type of sensor, the Arduino board can communicate with the sensor by digital or analogue ports.

- The Arduino board uses its input/output capabilities to periodically gather the humidity data from the sensor.
- The Arduino processes the gathered data using programming logic to translate the unprocessed sensor information into useful humidity values.
- The Arduino board manages the display unit and transmits the processed humidity values for display on the monitor.
- The power supply ensures that the Arduino board, humidity sensor, and display unit always have the power they require to function.

3.3 Calibrating sensor

The calibration process is crucial for obtaining accurate and dependable measurements from the humidity sensor. It entails comparing the sensor's readings with established humidity standards and modifying the sensor's output as necessary.

Importance of Calibration: Calibration ensures accurate and reliable measurements by removing systematic errors or biases in sensor readings. Inaccuracies in sensor output can be caused by environmental factors, aging, and manufacturing variations, necessitating calibration to eliminate them.

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3.4 Hardware setup

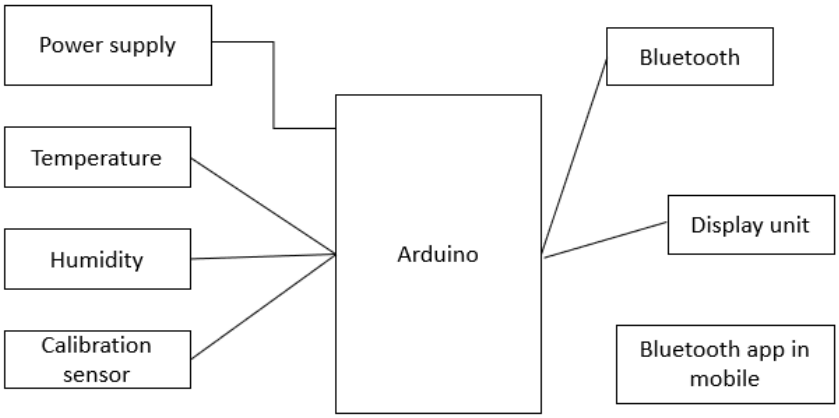

Figure 3.9 Hardware setup

3.4.1 Put the required parts together

- Boards for Arduino: Depending on the demands of the project, choose an appropriate Arduino board model.
- Humidity sensor: Pick a sensor with the ability to precisely gauge the humidity levels in the data control room. DHT11, DHT22, or the more accurate SHT series sensors are popular choices.
- Display device: Pick a display device that can show humidity readings in real time, like an LCD screen or an LED display.

3.4.2 Join the Arduino board to the humidity sensor

- Define the humidity sensor's pin configuration. It typically has signal/data (DATA), ground (GND), and power (VCC) pins.
- Join the 5V pin on the Arduino board with the VCC pin of the humidity sensor.

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- Join the GND pin on the Arduino board to the GND pin on the humidity sensor.
- Join the humidity sensor's DATA pin to an Arduino board digital input pin.

3.4.3 Ensure proper wiring and connections.

- Check the connections twice to make sure they are inserted securely.
- To organize and simplify management of the connections, think about using jumper wires or a breadboard.
- Keep wiring neat and secure to prevent errors or signal interference.
- Grounding properly and paying attention to the power supply are essential for accurate and stable measurement.

3.5 Software development

3.5.1 Installing the Integrated Development Environment (IDE) for Arduino

- From the official Arduino website (https://www.arduino.cc/en/software), download the most recent version of the Arduino IDE.
- Adhere to the Arduino IDE's installation guidelines for your particular operating system.
- Open the Arduino IDE after installation to start configuring the Arduino board.

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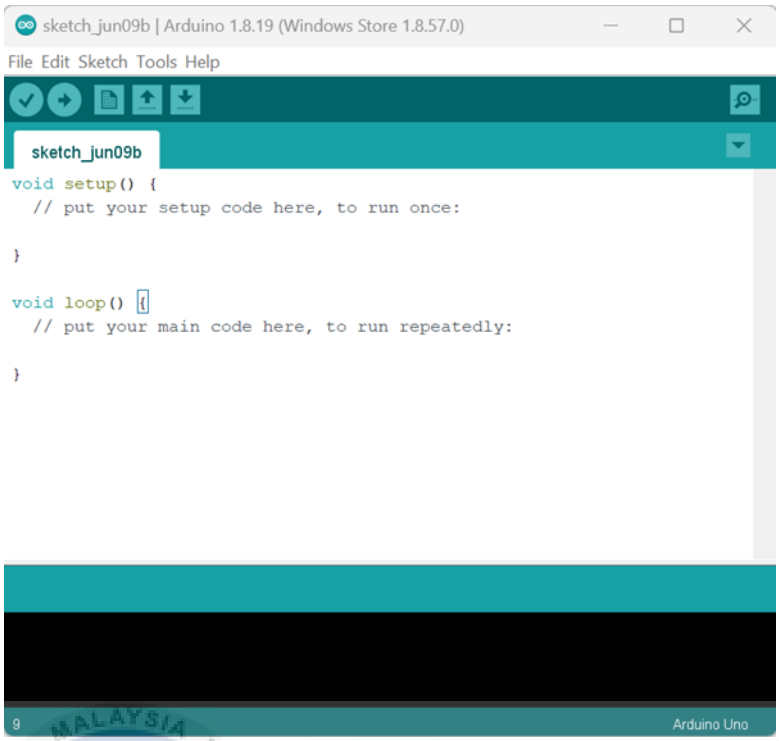

Figure 3.10 Arduino IDE

3.5.2 Installing the Bluetooth Serial Monitor

There are multiple steps involved in installing the Bluetooth Serial Monitor, and the exact procedure may change based on the hardware and software components that are being used. In electronics and Internet of Things projects, Bluetooth serial monitoring is an essential tool that enables wireless communication between devices via the Bluetooth protocol. This technology offers flexibility in design and deployment by doing away with the requirement for physical connections. To assist both seasoned developers and enthusiasts interested in wireless communication for their projects, we go over the principles, uses, and implementation of Bluetooth Serial Monitoring in this guide.

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- Make sure the required Bluetooth drivers are installed on your computer. Most contemporary operating systems have built-in Bluetooth support, but depending on your Bluetooth module, you might need to install extra drivers.
- In the Arduino IDE, go to "Tools" > "Serial Monitor" or use the shortcut (Ctrl + Shift + M) to open the Serial Monitor window. Make sure the correct COM port is selected in the Serial Monitor to match the port to which your Arduino is attached.
- Turn on the Bluetooth module. If necessary, turn on your circuit and set your Bluetooth module to pairing mode. For detailed instructions on how to enter pairing mode, consult the documentation for the module.
- Couple using a computer: Workstation Configuring Bluetooth: Navigate to the Bluetooth settings on your PC, look for compatible devices, and pair your Bluetooth module with it.
- Serial Output: In the Serial Monitor, you should observe the output generated by your Arduino sketch. Depending on your application, this could be messages, sensor data, or any other type of information.
- Troubleshooting: If problems occur, make sure the Bluetooth module is configured correctly, check your connections again, and confirm that the baud rates on the module and the Arduino sketch match.

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Figure3.11 Bluetooth Serial Monitor

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3.5.3 Develop the code to communicate with the Arduino board and humidity sensor

- Open the IDE and create a new Arduino sketch.
- List any libraries or dependencies that must be declared to function with the humidity sensor (such as Adafruit_Sensor.h and DHT.h).
- Set up the variables that are required to hold the humidity readings.
- Using the proper library functions, configure the Arduino board's communication with the humidity sensor.
- Create some code to read the sensor's data on humidity and store it in the specified variable.

3.5.4 Execute the required data acquisition and processing algorithms

- Include data acquisition algorithms based on the desired functionality, such as reading the sensor values at predetermined intervals.
- Use any necessary data processing methods, such as averaging or filtering, to ensure precise and consistent humidity readings.
- To handle exceptional cases, think about implementing error handling procedures or data validation checks.

3.5.5 Set up the display device to display current humidity readings

- If an LCD screen is being used, connect it to the Arduino board using the designated pin arrangement.
- Add the required libraries or dependencies (like Liquid Crystal.h) to interface with the display unit.
- Write code to set up any necessary configurations (such as the number of columns and rows) and initialize the display unit.
- Use the appropriate library functions to display the current humidity readings on the display unit.

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3.6 Data Acquisition and Processing

After assembling the hardware components and connecting the Arduino to the humidity sensor, the next step is to configure the Arduino to collect and analyse humidity data. The next phase focuses on the techniques required to build data processing algorithms for analysis and interpretation, store acquired data, and obtain data at frequent times.

3.6.1 Putting up Data Gathering

- Assess the ideal time interval for humidity data collection. This time frame will be determined by the particular demands of your monitoring system as well as the speed at which the humidity in the control room varies.
- To make sure that the humidity sensor is read at the predetermined interval, set up a timer or use delay functions in the Arduino code.
- Set up the analogy-to-digital converter (ADC) on the Arduino to accept and transform the analogue output of the humidity sensor into processable digital data.

3.6.2 Storing Acquired Data

- Choose whether to save the humidity data that was collected in the Arduino's memory or an external storage system like an SD card or a computer.
- Declare variables or arrays to hold the humidity readings if you plan to store the data in the Arduino's memory.

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- To write data to an external storage device, connect the Arduino to the storage device using the proper interfaces (e.g., SPI, I2C, serial), and then use libraries or write code to do so.

3.6.3 Display and Visualization

- Present processed data and real-time humidity readings on a display module (such as an LCD or OLED).
- Create code to update the display with the most recent humidity readings and any pertinent information obtained from the data processing algorithms.

- Think about displaying humidity trends over time visually using graphical representations like charts or graphs.

3.6.4 Error Handling and Validation

- Put error handling procedures in place to make sure the data collecting and processing phases are dependable and robust.
- Incorporate error checks for sensor issues, communication issues, or corrupted data.
- Check the acquired data's accuracy by comparing it to established reference values or by calibrating the humidity sensor.

3.6.5 Testing and Improvement

- Thoroughly test the functionality for data collecting and processing to make sure they adhere to system requirements.
- Check to make sure the data is stored, processed, and displayed appropriately.
- Assess how well the algorithms used for data processing understand humidity data and initiate the necessary steps.
- Based on test findings, user comments, and any areas that could use improved, iterate and optimise the algorithms.

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3.7 Performance Assessment

Several tests and measurements were made in order to assess the effectiveness of the humidity monitoring system for the data control room. The system's precision, dependability, and responsiveness in measuring and tracking humidity levels were the main

subjects of the review. To confirm the efficiency of the system, the measured humidity values were contrasted with established standards or known references.

3.8 Validation and testing

Run a series of tests to ensure the humidity monitoring system's performance and dependability**:**

a) Experiment with different humidity levels within the specified measurement range to test the sensor readings.

b) Check to see if the system accurately records and displays humidity values in real time.

c) Run tests to confirm that the system can withstand humidity swings and deliver consistent and steady measurements.

d) Test the system's capacity to detect and respond to humidity changes in a timely manner.

In terms of precision, response time, and stability, evaluate the system's performance**:**

a) Calculate the percentage difference between the system's readings and the reference measurements to determine the system's accuracy.

b) Determine the response time of the system by examining how quickly it detects and responds to changes in humidity levels.

c) Assess the system's stability by subjecting it to various environmental conditions and assessing if it maintains consistent and reliable operation.

Identify and address any potential problems or constraints that may arise during testing**:**

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a) Record any problems or restrictions discovered throughout the testing process.
b) Investigate the underlying causes of any inconsistencies or performance gaps.
c) Adjust or modify the hardware, software, or calibration procedure as needed to address detected concerns.
d) Repeat the testing process after applying the changes to check that the solutions are effective.

3.9 System Installation

Ensure that the system components are securely and accurately installed in the designated locations while installing the humidity monitoring system in the data control room.When installing the system, adhere to all safety standards and laws.

1. Ensure proper sensor and display unit placement for optimal monitoring**:**

- Place the humidity sensor in an area that accurately depicts the control room's overall humidity levels.
- Position the display unit in a visible area for easy monitoring and reading.

2. Validate the system's performance in a real-world environment**:**

- After installation, monitor the system's operation and performance.
- Check that the system is still providing accurate and dependable humidity readings in the operational environment.

3. Provide user training on system operation and maintenance**:**

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- Provide training sessions to users who oversee operating and maintaining the humidity monitoring system.
- Train users on system functions, data interpretation, and troubleshooting techniques.
- Distribute documentation or user manuals to assist users with system operation and maintenance.
- Share documentation or user manuals to guide users in system operation and maintenance tasks.

3.10 Summary

This chapter presents the proposed methodology, the study's significant findings and accomplishments.

- Creation of the data control room humidity monitoring system.
- Based on the testing and validation results, discuss the system's correctness, dependability, and stability.
- Address any limitations or areas for future improvement, such as prospective hardware, software, or calibration methods changes.
- Discuss the consequences and potential uses of the humidity monitoring system built, such as maintaining ideal ambient conditions for data storage and equipment performance.
- Stress the significance of ongoing monitoring and maintenance to ensure the system's long-term efficacy.

The methodology ensures accurate and dependable monitoring of humidity levels for successful control room management by following this full testing and validation process and appropriately placing the humidity monitoring equipment in the data control room.

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CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Introduction

Maintaining proper humidity levels is crucial in data control rooms to preserve the integrity and dependability of sensitive equipment. This project focuses on integrating the DHT11 sensor with an Arduino microcontroller to monitor and show real-time humidity values. The concept uses an LCD monitor to give an effective solution for humidity control in data control rooms.

4.2 Results and Analysis

Data control rooms can efficiently monitor and control humidity levels if this project is completed correctly. The embedded DHT11 sensor delivers accurate real-time humidity readings, which are presented on the LCD screen immediately. This enables proactive efforts to maintain appropriate humidity conditions, assuring the stability and performance of the data control room equipment.

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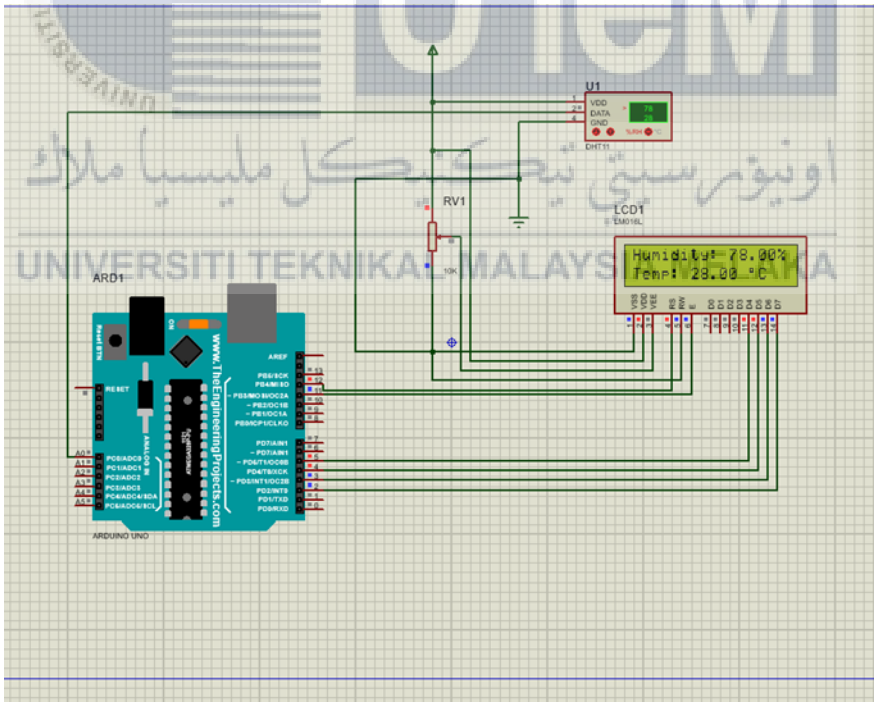
ddd

```
#define dht_apin A0

LiquidCrystal lcd(12, 11, 5, 4, 3, 2);
DHT dht(dht_apin, DHT11);

void setup()
{
  lcd.begin(16, 2); // 16 by 2 character display
  delay(500);
  lcd.setCursor(0, 0);
  lcd.println("Welcome to Microdigisoft");
  delay(500);
  lcd.clear();
  lcd.setCursor(0, 0);
  lcd.println("DHT11 Humidity & Temperature Sensor");
  delay(1000);
}

void loop()
{
  delay(2000); // Wait a second (recommended for DHT11)
  dht.read();

  lcd.clear();
  lcd.setCursor(0, 0);
  lcd.print("Humidity: ");
  lcd.print("dht.readhumidity");

  // Add more code here if needed

  delay(1000); // Adjust the delay according to your needs
}
```

```
Done compiling.
-d-gnu++11 -fpermissive -fno-exceptions -ffunction-sections -fdata-sections -fno-threads
o5fb78ea16e.a
```

Figures 4.1 Coding for the proteus

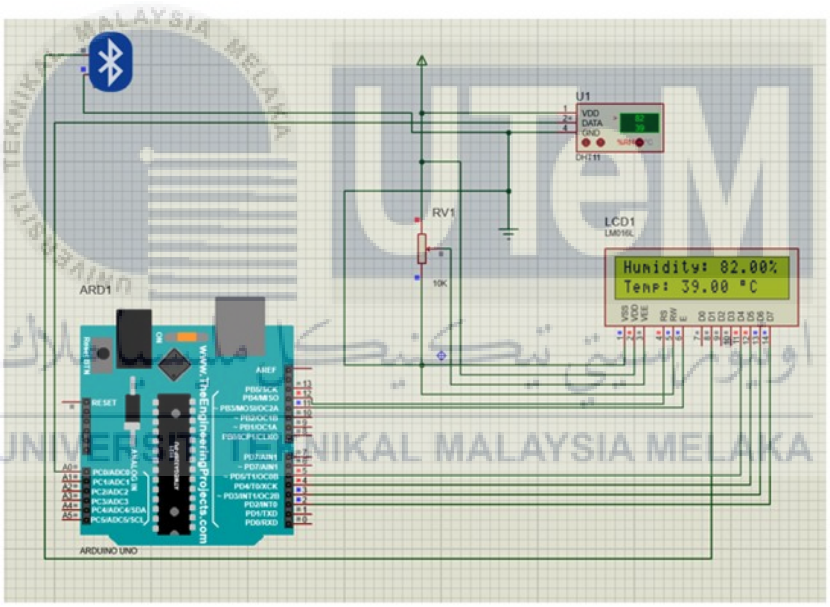


Figures 4.2 Circuit for the proteus

just_now

```
#include <dht.h>//Import DHt11 library
#include <LiquidCrystal.h> //import LCD libray
LiquidCrystal lcd(12, 11, 5, 4, 3, 2);// Initilize LCD library with 4bit ode
#define dht_apin A0 // sensor is connected to Analog Pin
dht DHT;// DHT variable to handle sensor functions
void setup()
{
  lcd.begin(16, 2); // LCD character display
}
void loop() {
  delay(2000); //wait a sec (recommended for DHT11)
  DHT.read11(dht_apin);
  lcd.clear();
  lcd.setCursor(0, 0);
  lcd.print("Humidity: ");
  lcd.print(DHT.humidity);// Print DHT11 reading for Humidity
  lcd.print("%");
  lcd.setCursor(0, 1);
  lcd.print("Temp: ");
  lcd.print(DHT.temperature);// Print DHT11 reading for Temperature
  lcd.setCursor(12, 1);
  lcd.print( (char)223); // displaying degree symbol (Â°).
  lcd.print("C");
}
```

Figures 4.3 Coding for the DHT11 circuit



Figures 4.4 DHT11 circuit with Bluetooth module

This code is about an Arduino experiment that demonstrates temperature and humidity information in real time on an LCD screen and sends it via Bluetooth.

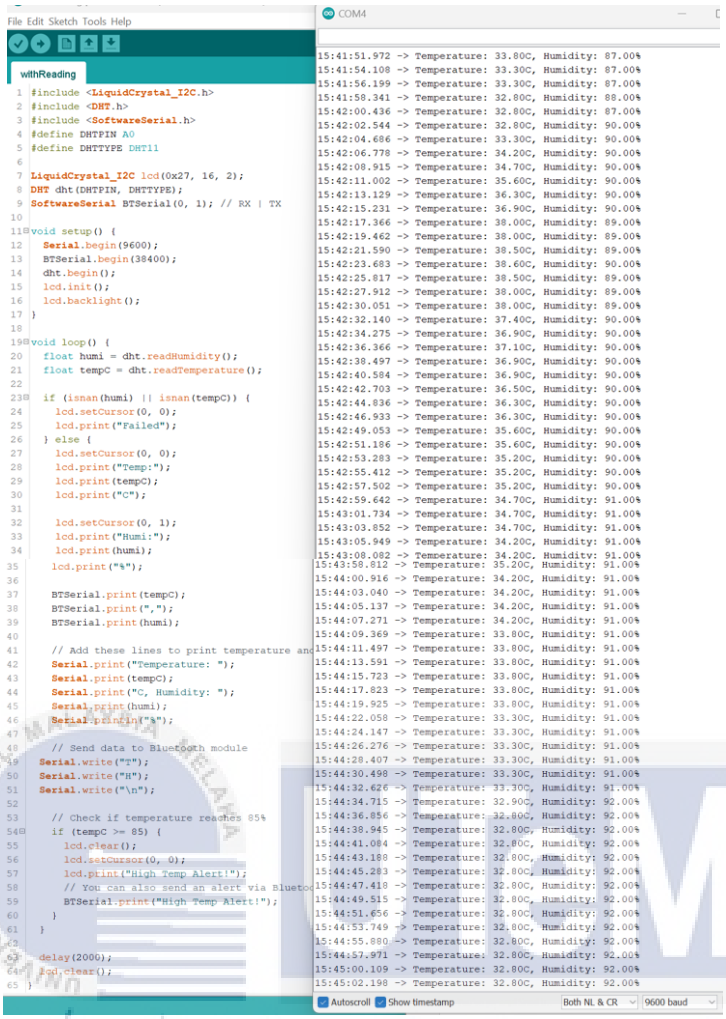


Figure 4.5 Hardware Coding and Reading

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In Addition To Knowledge And Experience:

- LiquidCrystal_I2C library - for controlling the LCD display.
- DHT library - to obtain temperature and humidity from a DHT11 sensor Software.
- Serial - to communicate via Bluetooth.

In setup ():

- The Serial monitor, Bluetooth module, DHT sensor, and LCD are initialized.
- The LCD backlight is turned on.

In loop ():

- It reads the humidity and temperature from the DHT11 sensor.
- Displays the values on the LCD screen.
- Sends the values over Bluetooth as CSV data.
- Prints the values to the Serial monitor.
- If temperature reaches 85C, it displays a warning on the LCD and sends an alert over Bluetooth.

So, it is reading sensor data, displaying it locally, transmitting it wirelessly, and monitoring for high temperature alerts. The time stamp indicates when this data reading occurred.

Figure 4.6 Bluetooth app reading

How The Arduino Code Works Together With A Bluetooth App:

- The Arduino code uses a DHT11 sensor, LCD screen, and Bluetooth module to constantly examine temperature and humidity values, display them on the LCD, and transmit them as CSV information through Bluetooth.

- A mobile app on a smartphone can connect to the Bluetooth module to receive this streaming sensor data, parse the CSV values, display the readings in real-time charts, visualize trends, display for indicators like excessive temperature warnings despatched by using the Arduino, log the data, and potentially provide faraway controls.

- Thus developing an built-in Internet-of-Things system the place the Arduino acts as the hardware hub gathering sensor facts and the cell app wirelessly connects to it for status updates, notifications, visualization, and control capabilities.

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HARDWARE EXPLANATION

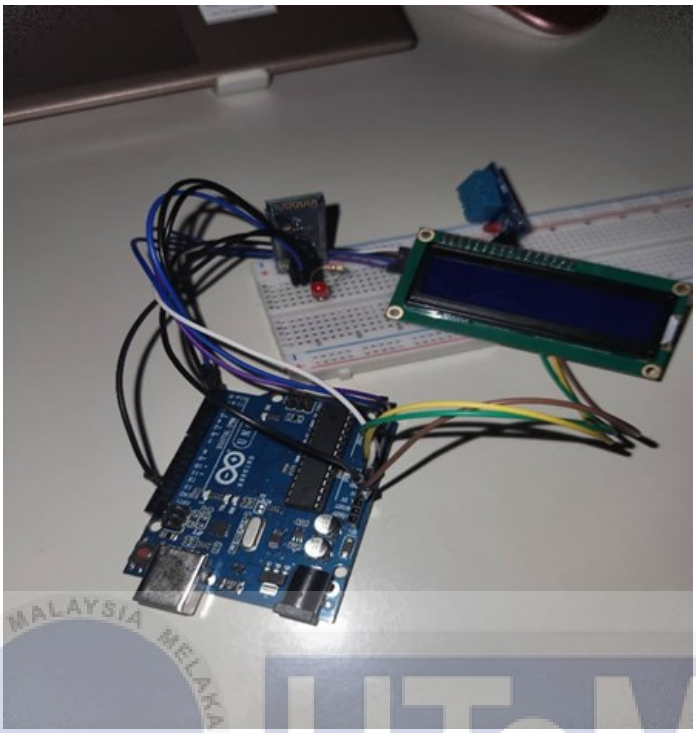

Figure 4.7 Hardware

How The Arduino Code Works When Uploaded To The Hardware Circuit:

The Arduino board linked to a DHT11 sensor, I2C LCD display, and Bluetooth module consistently samples temperature and humidity data each and every 2 seconds when the code is uploaded and runs - the LCD display screen initializes to display the present day readings, DHT11 starts off evolved sampling and updating the LCD, Bluetooth module transmits CSV records of values, and Serial reveal prints the information if connected to a computer. The device monitors the temperature, and if it exceeds 85C, shows a "High Temp Alert!" on the LCD and transmits the alert by Bluetooth. Overall, the circuit provides real-time environmental monitoring with local LCD display, Bluetooth transmission to paired devices, temperature alert notifications, and logging functionality when attached to a pc - enabling remote monitoring and control when paired with a smartphone app.

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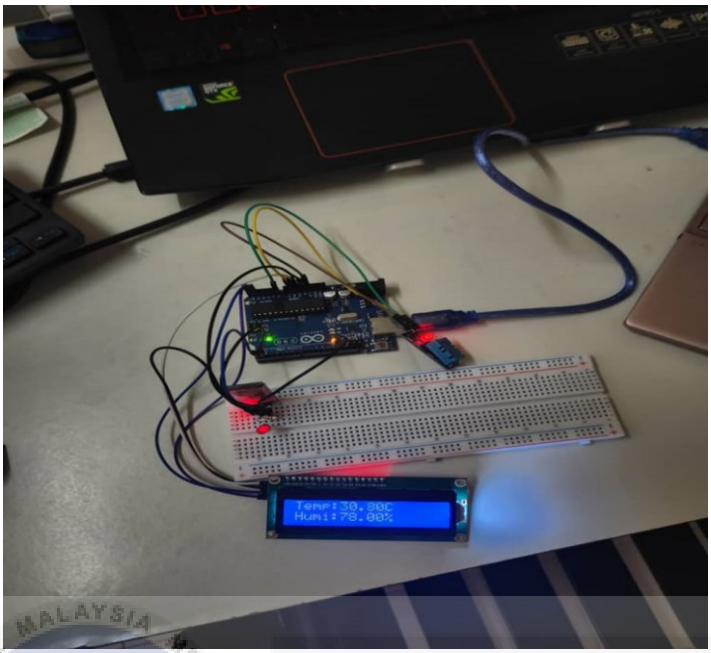

Figure 4.8 Hardware Reading of lower than 80%

Figure 4.9 Hardware Reading of over 80%

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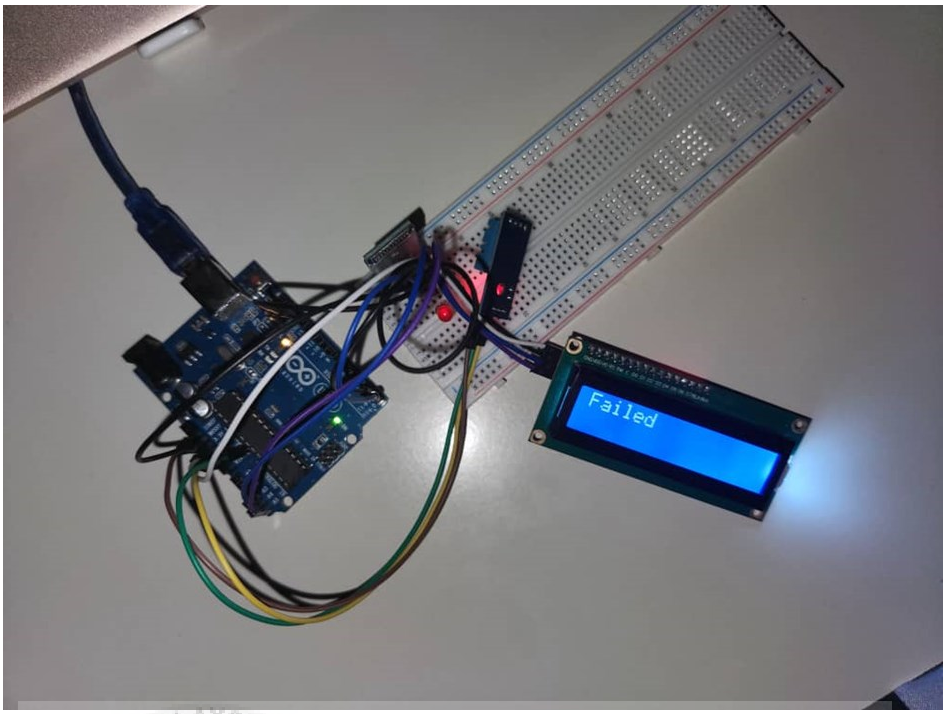

Figure 4.10 Failed

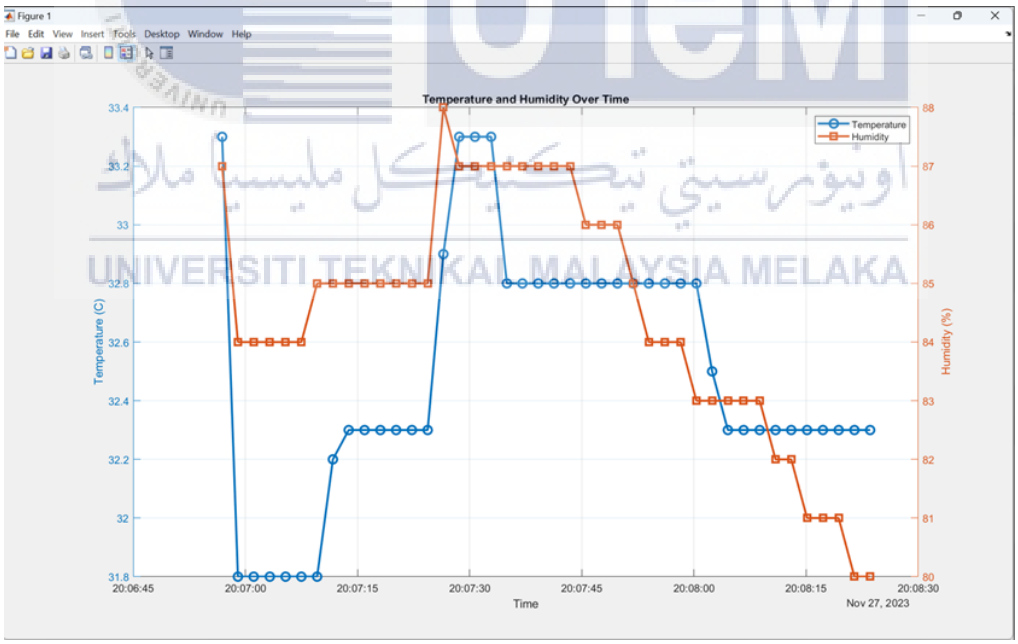

Figure 4.11 MATLAB Graph

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This MATLAB code converts timestamp strings to datetime objects and creates a grouped bar plot illustrating the variant of temperature and humidity over time. The x-axis represents timestamps, and each timestamp has two bars corresponding to temperature and humidity values. The legend distinguishes between temperature and humidity, and a grid is introduced for clarity. The resulting plot affords a visible illustration of the temporal tendencies in temperature and humidity data.

4.3 Summary

Real-time humidity readings are properly visualized using an LCD display, assisting in maintaining appropriate humidity levels. This setup's functionality and adaptability make it a valuable tool for areas where humidity control is crucial. Future advances may improve the system even further through enhanced data analysis and automation, resulting in better data control room performance and equipment reliability.

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CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This thesis Finally, developing a humidity monitoring system for a data control room entails researching and identifying the measuring process mechanism, building, and designing the product with appropriate parts and components, and testing its functionality. It becomes easier to ensure a safe and comfortable environment for both the electronic equipment and the individuals working in the control room by developing such a system.

5.2 Potential for Commercialization

The developed humidity monitoring device for records manipulate rooms holds extensive practicable for commercialization due to its critical role in making sure the top-quality functioning and longevity of digital equipment. The market demand for reliable environmental monitoring solutions, mainly in data centers, is substantial. Potential avenues for commercialization include:

- Data Centers and IT Infrastructure: Targeting statistics facilities and IT services in the place keeping unique environmental conditions is indispensable for equipment performance and longevity.
- Industrial Applications: Extending the system's applicability to a range of industrial settings where humidity control is essential for retaining product first-rate and equipment efficiency.
- Healthcare Facilities: Adapting the gadget for use in healthcare settings to guard sensitive scientific tools and make sure a managed environment.

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- Research Laboratories: Offering the device to lookup laboratories where specific environmental conditions are vital for experiments and tools reliability.
- Commercial Buildings: Providing solutions for business buildings, especially those housing sensitive electronic systems, to optimize electricity efficiency and gear performance.

To efficaciously commercialize the system, strategic partnerships, fine advertising campaigns, and ongoing lookup and improvement for product enhancements would be essential. Additionally, exploring possibilities for scalability, customization, and integration with different monitoring and manipulate structures would enhance the system's market appeal and doable for substantial adoption.

5.3 Recommendations for future study and improvements in humidity monitoring systems include:

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- More exploration of sophisticated sensor technologies to improve humidity measurement accuracy, dependability, and robustness.
- Develop of predictive analytics models that incorporate many data sources and parameters in order to enable proactive humidity control and equipment maintenance.
- Research into novel control strategies for real-time and dynamic humidity regulation, such as advanced machine learning algorithms and adaptive control systems.
- Integration of humidity monitoring systems with full environmental control systems,
- taking temperature, airflow, and air quality into account, to enable holistic and optimized data center operations.

- Ongoing research and development of energy-efficient and such as the Utilization of renewable energy sources and optimized cooling strategies.

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APPENDICES

Appendix A Gantt Chart for Final Year Project 1

Activity/ Task	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14
Project briefing, title selection, synopsis														
Identify objectives, problem statements														
Research reviews														
Model and component selection														
Methodology, design simulation														
Final report, presentation preparation														

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Appendix B Gantt Chart for Final Year Project 2

Activity/ Task	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14
Project planning and flowchart development														
Purchase of hardware														
Develop coding for DHT11 with Arduino hardware														
Completion of wiring for hardware														
Final testing														
Results compilation														
Documentation														

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Appendix C Arduino Coding

```
#include <LiquidCrystal_I2C.h>
#include <DHT.h>
#include <SoftwareSerial.h>
#define DHTPIN A0
#define DHTTYPE DHT11

LiquidCrystal_I2C lcd(0x27, 16, 2);
DHT dht(DHTPIN, DHTTYPE);
SoftwareSerial BTSerial(0, 1); // RX | TX

void setup() {
  Serial.begin(9600);
  BTSerial.begin(38400);
  dht.begin();
  lcd.init();
  lcd.backlight();
}

void loop() {
  float humi = dht.readHumidity();
  float tempC = dht.readTemperature();

  if (isnan(humi) || isnan(tempC)) {
    lcd.setCursor(0, 0);
    lcd.print("Failed");
  } else {
    lcd.setCursor(0, 0);
    lcd.print("Temp:");
    lcd.print(tempC);
    lcd.print("C");

    lcd.setCursor(0, 1);
    lcd.print("Humi:");
    lcd.print(humi);
    lcd.print("%");

    BTSerial.print(tempC);
    BTSerial.print(",");
    BTSerial.print(humi);

    // Add these lines to print temperature and humidity values to the Serial Monitor
    Serial.print("Temperature: ");
    Serial.print(tempC);
    Serial.print("C, Humidity: ");
    Serial.print(humi);
    Serial.println("%");
```

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```
    // Send data to Bluetooth module
  Serial.write("T");
  Serial.write("H");
  Serial.write("\n");

    // Check if temperature reaches 85%
    if (tempC >= 85) {
      lcd.clear();
      lcd.setCursor(0, 0);
      lcd.print("High Temp Alert!");
      // You can also send an alert via Bluetooth
      BTSerial.print("High Temp Alert!");
    }
  }

  delay(2000);
  lcd.clear();
}
```

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