“DESIGN AND CONSTRUCTION OF A THREE CUP DIGITAL ANEMOMETER WITH INTEGRATED WEATHER FORECASTING CAPABILITIES”

A report submitted to the Department of Mechanical Engineering.
Sonargaon University in fulfilment of the requirements for the course ME-400

Course Title: Project & Thesis

A Thesis

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Declaration

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Acknowledgment

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Abstract

This study describes the creation of an economical, solar-powered, effective cup-type anemometer. While the market is filled with many kinds of anemometers, our goal is to develop a tool that monitors temperature, humidity, and wind speed precisely. To guarantee accuracy and consistency in measurements, this study aims to attain a system error of only ±3%. We support sustainable energy practices by using solar power, one type of renewable energy, as the device's power source. We monitor wind speed, humidity, and temperature as the three primary factors in our study. The data is presented both physically and via an online application. Sensitive components, like the DHT11 sensor, are used by the anemometer as transducers to measure humidity and temperature in the surrounding air. The calibrated value of this digital anemometer.

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Chapter 1 Introduction

1.1 Introduction

The employment of sustainable energy resources is a critical response to the problems facing the environment today. Of these, wind energy is particularly promising because of its quantity and sustainability. Accurate wind speed measurement, which is often done by anemometers, is essential to effectively utilizing wind energy.

Antennas, which are instruments used to measure wind speed, are essential in many disciplines, such as geophysics, metrology, and meteorology. The simplicity and dependability of the cup anemometer, which has three wind-catching cups, set it apart from other anemometer kinds. In order for this gadget to function, the wind causes it to rotate, with the rotation speed being according to the wind speed.

The geometry of the rotors of cup anemometers affects their effectiveness; this has been the focus of much experimental and analytical research. To maximize the device's effectiveness and guarantee precise wind speed measurements, it is essential to comprehend these dynamics. Technological developments in anemometers have made it possible to detect meteorological parameters like temperature and humidity in addition to wind speed. Combining these features into one system increases the device's adaptability and usefulness, especially for applications that need to collect a lot of environmental data.

The use of an Arduino Nano control system augments the gadget's capabilities and permits a small and effective design.

Apart from data logging, the integration of an LCD display enables real-time monitoring. This feature makes it possible to visualize temperature, humidity, and wind speed data instantly, which offers insightful information for on-site analysis and decision-making.

In conclusion, the creation of a three-cup anemometer is a noteworthy accomplishment in the field of renewable energy monitoring technology. This device provides a comprehensive solution for evaluating wind potential and environmental variables in different situations by combining precise wind speed measurement with additional weather variable monitoring capabilities.

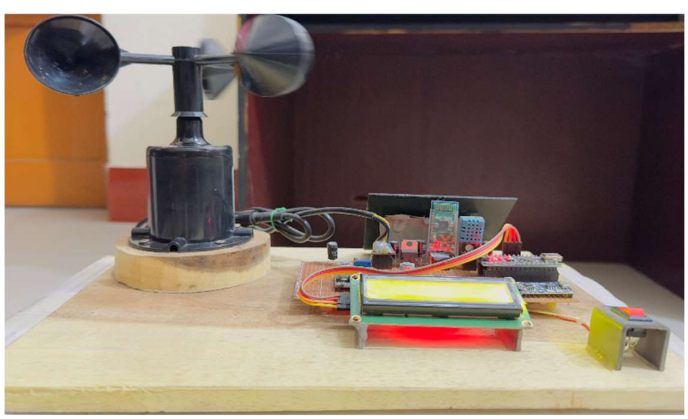

Figure 1: Constructed Digital Anemometer

1.2 Objectives

The objectives of the project are:

i. To design and construct a three-cup digital anemometer,
ii. To analyze the performance of the constructed anemometer under various weather conditions.
iii. To develop and improve anemometers.

1.3 Applications:

Weather Stations:

i. Tracking direction and speed of the wind to help with weather forecasting.
ii. Recognizing and forecasting patterns of the climate and severe weather.
iii. Evaluating air conditions for maritime and aviation operations.

Construction Projects (Tower Cranes):

i. Measuring wind speeds at various altitudes to ensure the safe operation of tower cranes.
ii. Preventing mishaps and enhancing crane functionality.
iii. Respecting safety rules and reducing weather-related downtime.

Bridge Monitoring:

i. Bridge monitoring involves the identification of structural vibrations in bridges caused by wind.
ii. Making certain that the infrastructure of bridges is safe and sound.
iii. The deployment of early warning systems for safety and maintenance procedures.

Agricultural Sector:

i. Monitoring where wind patterns impact pesticide application, pollination, and crop growth.
ii. Improving agricultural techniques and reducing the possibility of wind damage.
iii. Improving sustainability and productivity in agriculture.

Shipping Industry:

i. A safe navigation and route planning assessment of sea wind conditions is part of the Shipping Industry.
ii. Using wind data to optimize ship performance and fuel efficiency.
iii. Improving marine safety while lessening the effect of shipping operations on the environment

Aviation Industry:

i. Determining wind direction and speed for navigation and takeoffs.
ii. Improving fuel economy, flight safety, and flight planning.

Chapter 2 Literature Review

2.1 Related previous work

We conducted some background research and learned a little bit about the design and construction of a three-cup anemometer with integrated weather forecasting capabilities before beginning this project. We conceal certain earlier thesis papers for this reason, that as follows:

Leif Kristensen et al., [1]:- The cup anemometer, invented in 1846 by Irish astronomer Thomas R. Robinson, is a reliable instrument used to measure wind speed in various locations [1]. The factor f, the wind speed divided by the cup's speed, is a law of nature, but calibration cannot be linear. Anemometers with three cups are better due to their responsiveness to changes in wind speed. Schrenk and Wyngaard published a model to analyze over speeding in turbulent wind, which is a phenomenon where the output signal is larger for a particular mean-wind speed than the same instrument exposed to a constant wind speed [1].

Ken Okamoto et al., [2]:- The Abstract digital anemometer is a device designed to monitor air flow in residential and commercial settings. It uses hot-wire anemometry to detect flow rate and measure temperature [2]. The probe, consisting of a hot thermistor and a cool thermistor, has a thermal time constant of 0.2 s at high temperatures, ten times faster than traditional thermistors. The reference response is adjusted to balance the unbalance component caused by flow temperature. The probe's characteristic function is achieved by normalizing the imbalance voltage with a reference voltage, which deviates from King's law and is represented by a logarithmic function of flow rate v [2].

R Hern´andez-Walls et al., [3]:- An inexpensive digital anemometer has been designed and calibrated to measure wind velocity in two dimensions. The device uses a pendulum with a drag body to interact with fluid in motion, causing an angle with the vertical. The mouse measures the displacement of a sphere attached to the pendulum and calculates the angle, determining the relationship between drag force and wind speed [3]. A MATLAB script is written to process the data, reducing human error and time and cost associated with wind velocity measurement. The project aims to measure drag angle using an optical computer mouse on a sphere [3].

D. Lindley [4]:- Over the past 40 years, a cup wheel design with three conical cups with a cup arm to cup radius ratio of ~2.5 has evolved. The instrument response to sinusoidally fluctuating wind was determined in a 30.48 cmX30.48 cm square tunnel with a variable speed motor driving counter-rotating vane [4]. Calibration curves for polystyrene lipless 3-cup, metal arm anemometers at various R/r ratios showed that the smaller the arm length to cup radius ratio, the faster the cup revolution per unit speed. Tests on a staggered 6-cup assembly showed that wheel assemblies with cups with a 1.6 mm lip had the smallest distance constant and fasted response [4].

Guo-Zhen Li et al., [5]:- This paper presents a wearable anemometer that detects wind absolute orientation, speed, attitude, and heading angles using a micro homemade thermal flow vector sensor, triaxial micro accelerometer, and triaxial micro magnetometer. The sensor is made of three Pt hot films and measures flow speed and relative angle in the body coordinate system [5]. The anemometer uses a rechargeable lithium battery and can work for 4 hours under wind blowing. Experimental results show RMS errors in wind speed, relative angle, absolute orientation, heading, roll, and pitch [5].

Santiago Pindado et al., [6]:- A study at the IDR/UPM Institute examined the impact of anemometer rotor shape parameters on anemometer performance. The research involved calibrations on two different anemometers, 21 different rotors, and compared to classical analytical models. The results showed a linear dependency of calibration constants, slope and offset, on the cups' center rotation radius, with the front area also influencing the results. The study found a linear correlation between the coefficients A_r and the cups' center rotation radius, with a better regression coefficient. The 2-cup analytical method was used to study the aerodynamics of cup anemometers' rotors [6].

Triwahju Hardianto1 et al., [7]:- The research aims to create a real-time anemometer for wind power generation in Puger beach, Indonesia. The device uses a hall effect sensor, a compass sensor, and a real-time clock to measure wind speed, direction, and temperature. The system also includes a temperature sensor to determine air density. The research emphasizes the importance of proactive maintenance for wind turbine machines, utilizing remote control and monitoring. The device is based on a personal computer and Industry Standard Architecture bus, with data stored in microSD memory and an Arduino Uno control system.

Sree Bash Chandra Debnath et al., [8]:- The paper discusses the design and implementation of an efficient windmill anemometer using a microcontroller. The windmill type model uses a wind sensor to sense wind speed and rotates a shaft relative to it. The system uses a nobility method with a PIC microcontroller, liquid crystal display, operational amplifier, crystal oscillator, and proximity sensor to increase accuracy and management. The anemometer uses an infrared light-emitting diode (LED) to generate a single pulse when wind forces the shaft, and a proximity sensor to count rotation. The frequency is used in various applications, such as time tracking in quartz wristwatches and stabilizing frequencies for radio transmitters and receivers [8].

Samuel Kang'iri et al., [9]": - The global wind energy market is expected to reach USD170 billion by 2024, requiring wind data collected for turbine installation. However, commercial cup anemometers and wind vanes are often unaffordable for small-scale wind farmers, especially in developing countries. This paper presents a wireless 3D-printed cup-vane instrument for collecting wind data, representing a Wireless Sensor Node in the Internet of Things (IoT). The instrument can acquire wind data within a mean fitting deviation of ±0.063398 m/s, store it, and present it wirelessly to an IEEE 802.15.4 protocol sink node. The study aims to provide a reliable and robust instrument for measuring wind speed, enabling it to be networked for analysis and prediction.

Santiago Pindado, et al., [10]:- A 2015 study published in IOP science discusses an improved analytical method for studying cup anemometer performance. The cup anemometer, invented in the 19th century, is a commonly used wind speed sensor for wind turbine control and wind energy production forecast. The study includes a 3-cup analytical model, which includes the effect of rotation on the aerodynamic force and the displacement of the aerodynamic center during one turn of the cup. The model allows for better understanding of the effects of rotor asymmetries and the impact of rotational forces on the cup anemometer's performance.

Chapter 3 Design

3.1 Design Assumption

Based on the previously mentioned design assumptions, the anemometer was created. The plan was based on accurate wind flow sensing. It isassumed that the design will function in a reasonable range of wind speeds. The desired maximum speed was assumed to be within the range of 70 m/s. Frictionalloss and inertia are believed to be minimal. It is believed that the body's inertia will be overcome by the torque created by the minimal wind force. It was considered that the cups had complete air contact.

3.2 BOQ & BOM

Components of Constructed Anemometer:			
SL No	Description	quantity	valuation
1	Wind Speed Sensor (e.g., anemometer with a digital output or an analog sensor).	1	2950
2	DHT11 Humidity and Temperature Sensor.	1	185
4	Arduino board (e.g., Arduino Nano).	1	500
6	16x2 Serial LCD Module Display	1	340
7	Battery 9V	1	75
8	9V Battery connector	1	10
9	L7805 Voltage Regulator 5V	1	19
10	220uF/16v capacitor	2	10
11	Jumper wire 40 pcs set 20cm	1	100
12	Solar Panel 90x90mm 5v,200mA	1	528
13	DC-DC Boost Module	2	260
14	Arduino Bluetooth Module HC-05	1	337
16	Male pin header single row	1	10
17	On/Off switch Mini	2	12
19	Veroboard Dot Type	3	105
20	16 pin DIP IC Base /Socket	2	14
21	Rechargeable Battery	2	100
22	Anemometer Wood Base	1	200
24	Soldering Lead	2	160

25	Female pin header single row	2	30
	Sub Total Cost		5945
			E24*5%
			337.45
	Total		6282.45

3.3 Anemometer

The three-cup anemometer is one of the most common types of mechanical anemometers used for measuring wind speed. It consists of three cups mounted symmetrically on horizontal arms at equal distances from the center of a vertical axis. When the wind blows, the cups catch the wind and start to rotate around the central axis. The rotation speed of the cups is directly proportional to the wind speed.

The design of the three cups is such that they provide a balanced and consistent response to wind from any direction. This type of anemometer is simple, reliable, and relatively insensitive to wind direction changes compared to other designs. It's widely used in weather stations, research facilities, and environmental monitoring applications.

3.4 Difference Between Analog & Digital Anemometer

Analog Anemometer	Digital Anemometer
An analog Anemometer measures the speed of wind by comparing a Digital signal and ultimately Convert the Mechanical Input into Digital Output Signal.	A Digital Anemometer measures the speed of wind by comparing a Digital signal and ultimately Convert the Mechanical Input into Digital Output Signal.

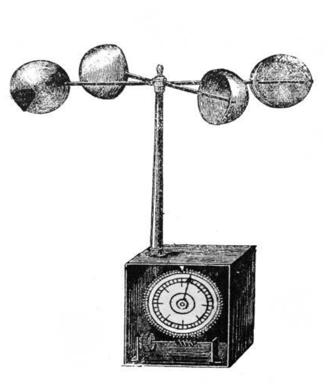

Figure 2 Analog Anemometer

Figure 3: Digital Anemometer

3.5 Programming

```
#include <Wire.h>
#include<SoftwareSerial.h>
SoftwareSerial B (10, 11);      // 10-RX, 11-TX, B men's Bluetooth

#include <LiquidCrystal_I2C.h>
LiquidCrystal_I2C lcd(0x27,20,4);     // Set the led address to 0x3F for a 16 chars and 2 line
display

#include <dht11.h>
#define DHT11PIN 4

dht11 DHT11;

unsigned long lastDebounceTime = 0;    // The last time the output pin was toggled
unsigned long debounceDelay = 1000;    // The debounce time: increase if the output flickers

void setup() {

B.begin(9600);

  lcd.init();
  lcd.clear();
  lcd.backlight();     // Make sure backlight is on
  lcd.setCursor(3, 0);
  lcd.print("Anemometer");
  delay(3000);
  lcd.clear();

}

void loop() {
  //DHT11

 int chk = DHT11.read(DHT11PIN);
 lcd.setCursor(8,0);
 lcd.print("Hu");
 lcd.setCursor(10,0);
 lcd.print((float)DHT11.humidity, 2);
 lcd.setCursor(15,0);
 lcd.print("%");
 B.print((float)DHT11.humidity, 2);
 B.print(" %");
 B.print(",");

 lcd.setCursor(8,1);
 lcd.print("Te");
 lcd.setCursor(10,1);
 lcd.println((float)DHT11.temperature, 2);
 lcd.setCursor(15,1);
 lcd.print("C");
 B.print((float)DHT11.temperature, 2);
 B.print(" C");
 B.print(",");

  ////////////////////////////////
```

```
  int sensorValue = analogRead(A0);
  float outvoltage = sensorValue*(5.0/1023.0);
  float Level = 6*outvoltage;    //The level of wind speed is proportional to the output voltage.

  lcd.setCursor(0, 0);
  lcd.print("Wind S");
  lcd.setCursor(0, 1);
  lcd.print(Level);
  lcd.setCursor(4, 1);
  lcd.print("M/S");

  B.print(Level);
  B.print(" M/S");
  B.print(";");

  delay(1);
}
```

Chapter 4 Materials and Methodology

4.1 Materials

The raw materials that were utilized for this construction are described below:

4.1.1 Anemometer

The three cups type wind speed sensor voltage Type (0-5V) Anemometer Kit is an instrument that can measure the wind speed. It is composed of shell, wind cup, and the circuit module. Photovoltaic modules, industrial Microcontroller processors, the current generator, electric current and so on are integrated into the internal drive.

Features of Anemometer:

i. High hardness, Corrosion protection.
ii. Waterproofness and High precision.
iii. The mode of its Output signal: 0-5V (Voltage signal)
iv. Start wind spped:0.4-0.8 m/s.

Figure 4: Three Cup Anemometer

4.1.2 Arduino Nano

Arduino nano is a small compact version of the Arduino microcontroller board. It is designed for projects that require a small footprint and lower power consumption designs based on the ATmega328P microcontroller and has a similar set of features as the Arduino Uno.

Features of Arduino Nano:

i. USB Driver:CH340
ii. Operating voltage (logic level):5V
iii. With mini-USB
iv. 8 analog inputs Ports: A0-A7
v. 14 Digital input/Output ports: TX, RX, D2-D13
vi. Manual reset switch.

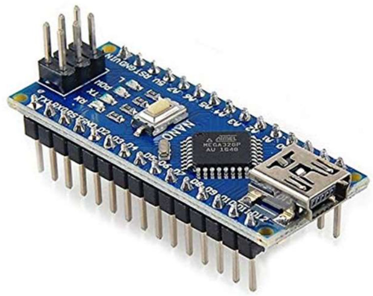

Figure 5: Arduino Nano

4.1.3 16x2 LCD Display

A liquid-crystal display (LCD) is a flat panel display or other electronically modulated optical device that uses the light-modulating properties of liquid crystal. Liquid crystals do not emit light directly, instead usinga backlight or reflector to produce images in color or monochrome. LCDs areavailable to display arbitrary images (as in a general-purpose computer display) or fixed images with low information content, which can be displayed or hidden,such as preset words, digits, and seven segment display, as in a digital clock.

Figure 6: LCD Display

4.1.4 DHT11 Humidity and Temperature Sensor

Both the DHT11 and DHT22 are popular humidity and temperature sensors commonly used in various projects.

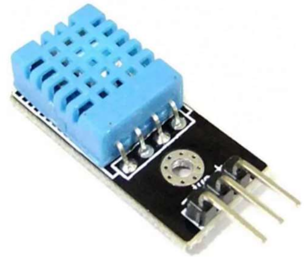

Figure 7: Humidity & Temperature Sensor

4.1.5 Solar panel

A solar panel measuring 90mm x 90mm with a rating of 5V and 200mA can generate up to 5 volts of electrical potential difference and can deliver a maximum current of 200 milliamperes (mA) under ideal conditions, such as direct sunlight.

Figure 8: Solar Panel

4.1.6 DC-DC Boost Module:

A DC-DC boost module, also known as a boost converter or step-up converter, is an electronic circuit used to increase the voltage of a direct current (DC) power source to a higher level. This type of module is commonly used in various applications where a higher voltage than the input source is required, such as in battery-powered devices, solar energy systems, and LED lighting.

Figure 9: DC-DC Boost

4.1.7 Arduino Bluetooth Module

The Arduino Bluetooth Module HC-05 is a commonly used Bluetooth serial communication module that allows Arduino microcontrollers to communicate wirelessly with other Bluetooth-enabled devices such as smartphones, tablets, and computers.

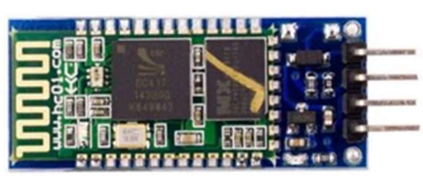

Figure 10: Arduino Bluetooth Module

4.1.8 Capacitor

A 220uF 16V capacitor is an electrolytic capacitor commonly used in electronic circuits for various applications such as smoothing voltage fluctuations, filtering noise, and storing charge.

Figure 11: Capacitor.

4.1.9 On/Off Switch (mini)

This indicates that the switch has two positions: one for turning the circuit on and one for turning it off. When the switch is in the "on" position, it allows current to flow through the circuit, and when it's in the "off" position, it interrupts the flow of current.

Figure 12: On/ Off Switch (Mini)

4.2.1 Veroboard Dot Type

A Veroboard Dot Type, also known simply as "dot board" or "perfboard," is a type of prototyping board used in electronics for building and testing circuits. It is similar to stripboard (or Veroboard) but has individual pads or dots for soldering components instead of continuous copper strips.

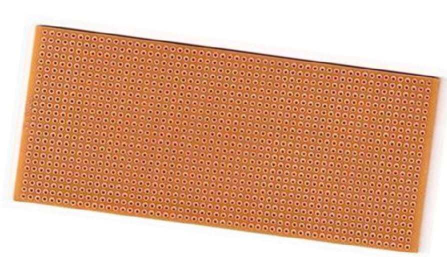

Figure 13: Veroboard.

4.2.2 Voltage Regulator

The L7805 is a popular voltage regulator integrated circuit (IC) that provides a fixed 5-volt output voltage. It's part of the 78xx series of voltage regulators manufactured by various semiconductor companies. The "78" in the series name indicates that it is a positive voltage regulator, and "05" signifies the output voltage of 5 volts.

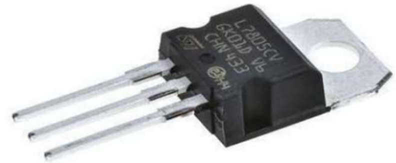

Figure 14: Voltage.

4.2.3 Battery

A 3.7-volt battery is a common type of lithium-ion rechargeable battery. These batteries are widely used in various electronic devices such as smartphones, tablets, digital cameras, and portable power banks. The voltage rating of 3.7 volts refers to the nominal voltage, which is the average voltage output over the discharge cycle of the battery. It's important to note that the actual voltage of a lithium-ion battery can vary depending on its state of charge and load conditions.

Figure 15: Battery.

4.2.4 Jumper wires (Male to female)

Jumper wires with male connectors on one end and female connectors on the other end are used to make connections between male pins on one component (like a microcontroller or sensor) and female headers or pins on another component (like a breadboard or a shield).

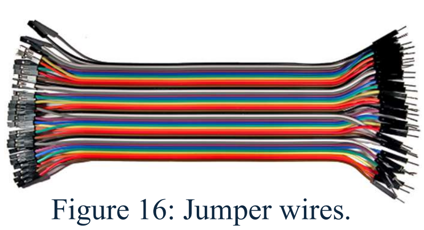

Figure 16: Jumper wires.

4.3 Methodology

Signal Processing: The electrical signals generated by the sensors are processed by digital circuitry. This processing may involve amplification, filtering, and analog-to-digital conversion to prepare the signals for further analysis.

Calibration: Digital anemometers need to be calibrated to ensure accurate measurements. Calibration involves comparing the anemometer's readings to those of a reference standard under controlled conditions. Corrections may be applied to the measurements based on the calibration results.

Display and Output: The processed wind speed data is typically displayed on a digital screen in units such as meters per second (m/s), kilometers per hour (km/h), miles per hour (mph), or knots. Some digital anemometers may also provide additional features such as logging capabilities, data output ports (e.g., USB), and wireless connectivity for remote monitoring.

Power Source: Digital anemometers require a power source to operate. This can range from built-in batteries for portable units to external power sources for fixed installations.

Environmental Consideration: Digital anemometers may need to be weatherproof or designed to withstand harsh environmental conditions, especially if they are used outdoors or in

4.4 Circuit Diagram

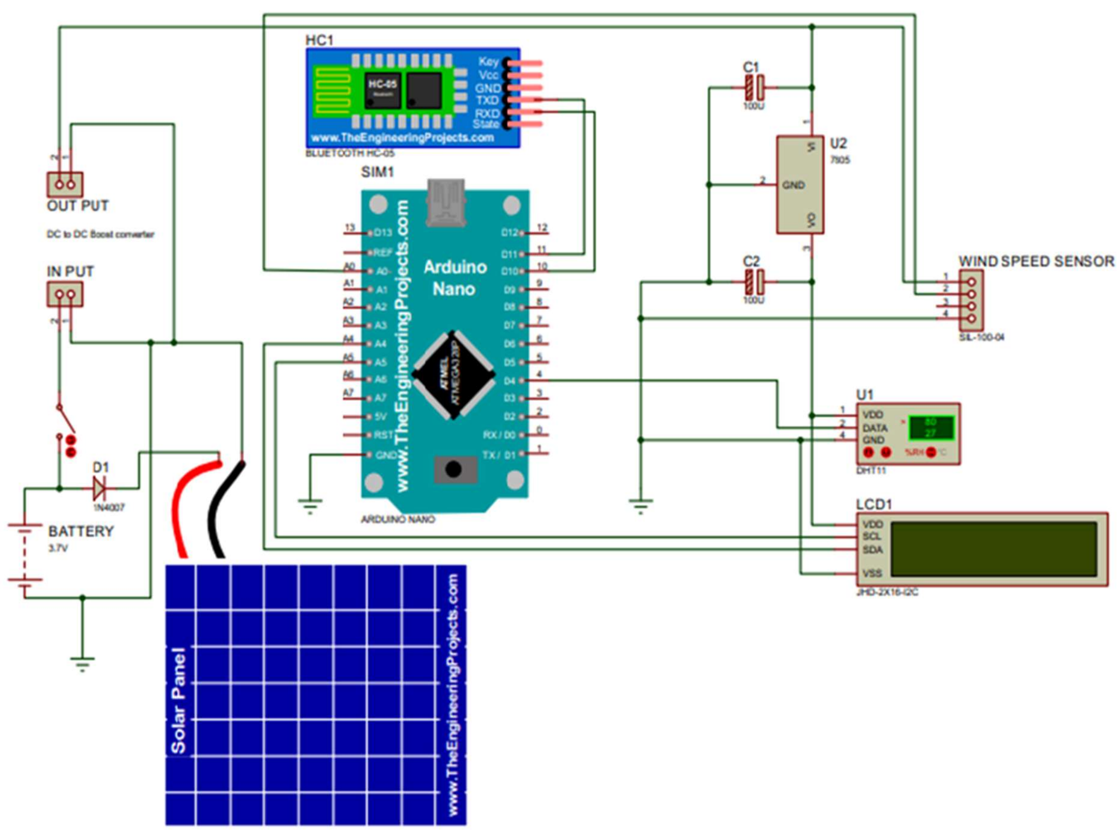

Figure 17: Circuit Diagram

4.5 Block Diagram

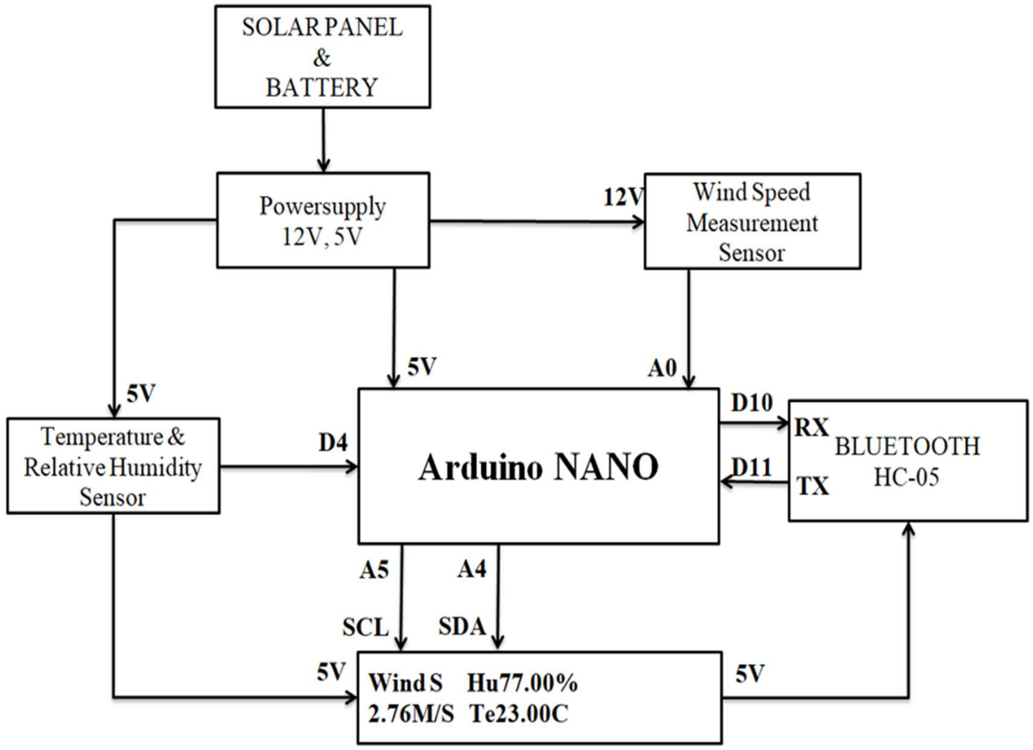

Figure 18: Block Diagram

4.6 Working Principle

This flowchart provides a step-by-step breakdown of the mechanical and electronic processes involved in measuring wind speed with a three-cup digital anemometer, enhanced with humidity and temperature sensing capabilities.

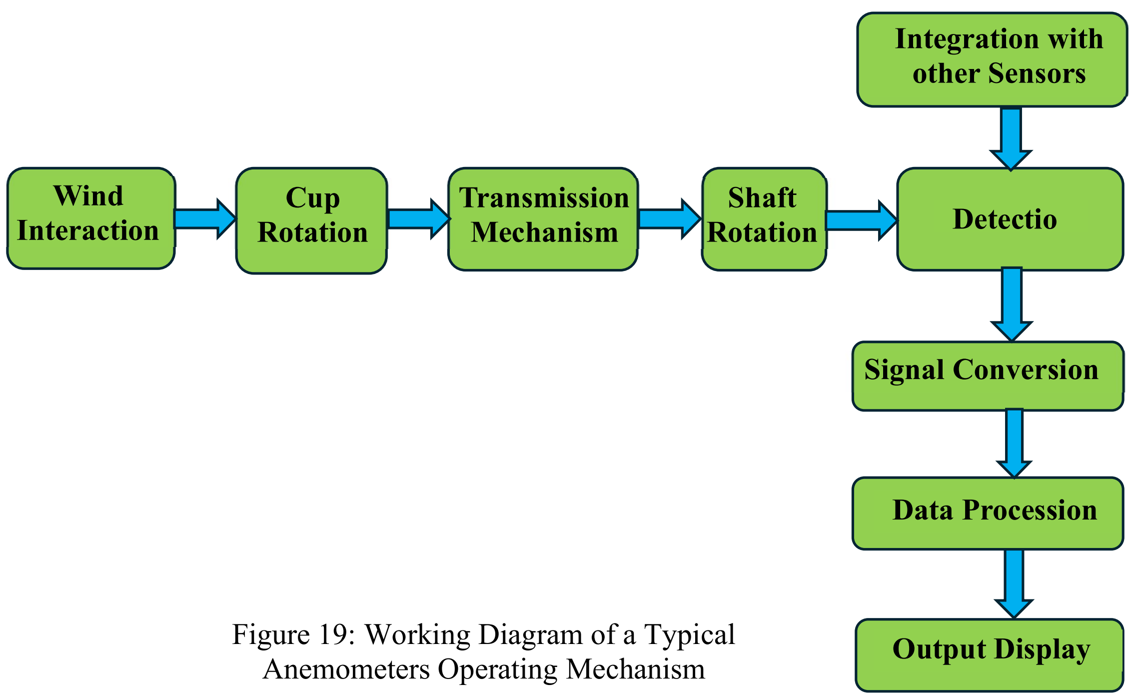

Figure 19: Working Diagram of a Typical Anemometers Operating Mechanism

Three cylindrical cups attached to horizontal arms that are connected to a central vertical rod so they can rotate around a central axis make up the device's design. The cups are rotated by a shaft positioned within the axis. The cups and shaft rotate faster with increasing wind speed. Using an analog or digital wind meter, the number of rotations is counted and calibrated to determine the wind speed. We're also adding a temperature and humidity sensor. Humidity sensors are electronic devices that measure the humidity in an environment and translate the data into an electrical signal that can be utilized for various purposes. It's possible that you heard a distinct humidity sensor. DHT11 is what we use. The actual definition of humidity is the amount of water present in the air. Measuring the amount of water vapor in the air is crucial because it can significantly impact both our daily lives and various industrial processes. So, when the question arises in the future, "What is a humidity sensor and why is it important?" You will then understand how crucial they are to all facets of our daily lives, as humidity affects physical, chemical, and biological processes. This quantity is measured by air humidity sensors, which then transform the data into a readable format for external use. The way humidity sensors are made allows them to pick up on any changes in the temperature of the air or electrical currents.

4.7 Final Constructed Project View

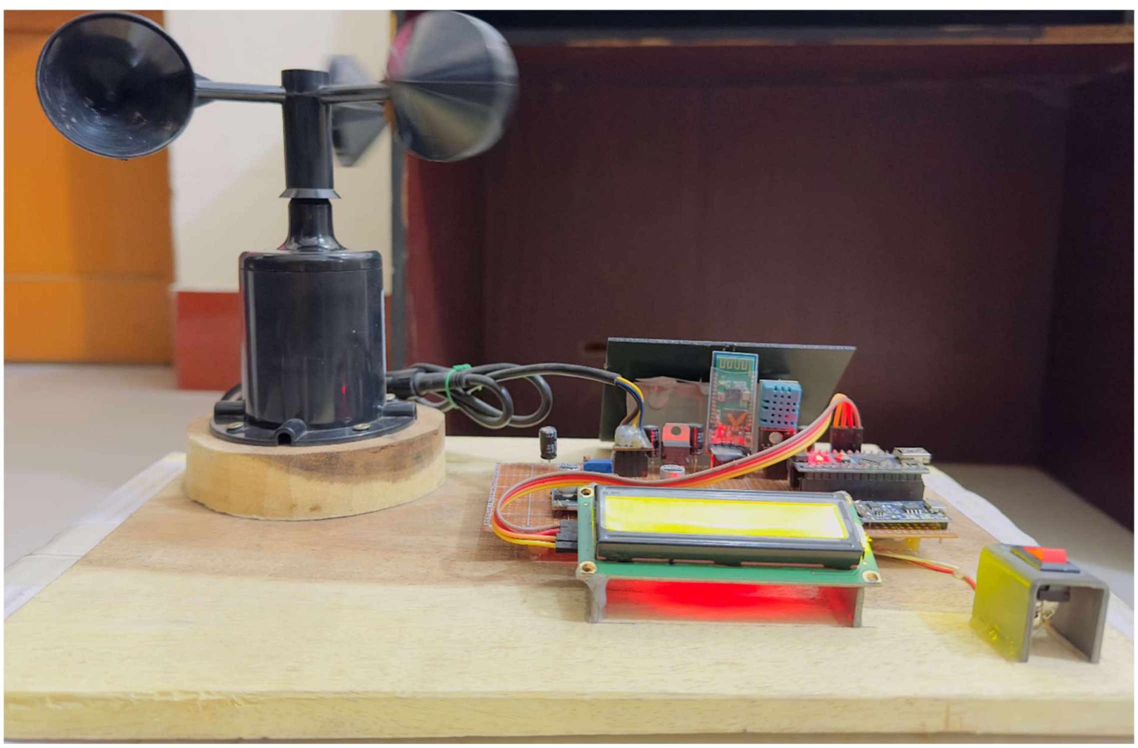

Figure 20: Final Constructed Project View

Chapter 5 Result and Discussion

5.1 Wind Speed Comparison between Constructed and Standard Anemometer

Table 1: Experimental data of wind speed for constructed and standard anemometer.

No of Observation	Constructed Anemometer Speed (m/s)	Standard Anemometer Speed (m/s)
	Wind speed m/s	**Wind speed m/s**
1	1.7	1.8
2	2.5	2.4
3	3.1	3.2
4	3.8	3.6
5	4.5	4.1

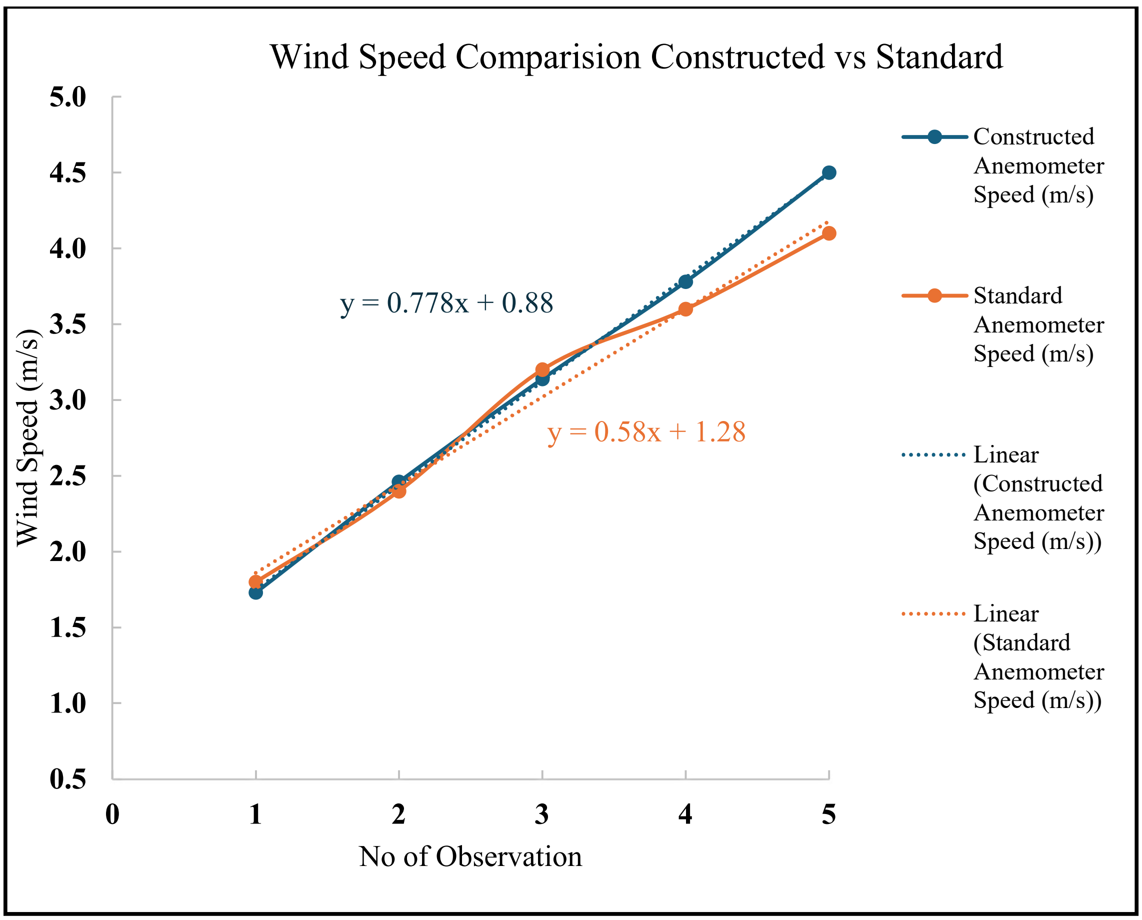

Figure 21: Wind Speed Comparison Constructed vs Standard.

5.2 Humidity Comparison between Constructed and Standard Anemometer

Table 2: Experimental data of humidity for constructed and standard anemometer

No Of Observation	Constructed Anemometer	Standard Anemometer
	Humidity (%)	Humidity (%)
1	74.00%	73.90%
2	74.00%	73.88%
3	75.00%	74.85%
4	75.00%	74.90%
5	76.00%	75.85%

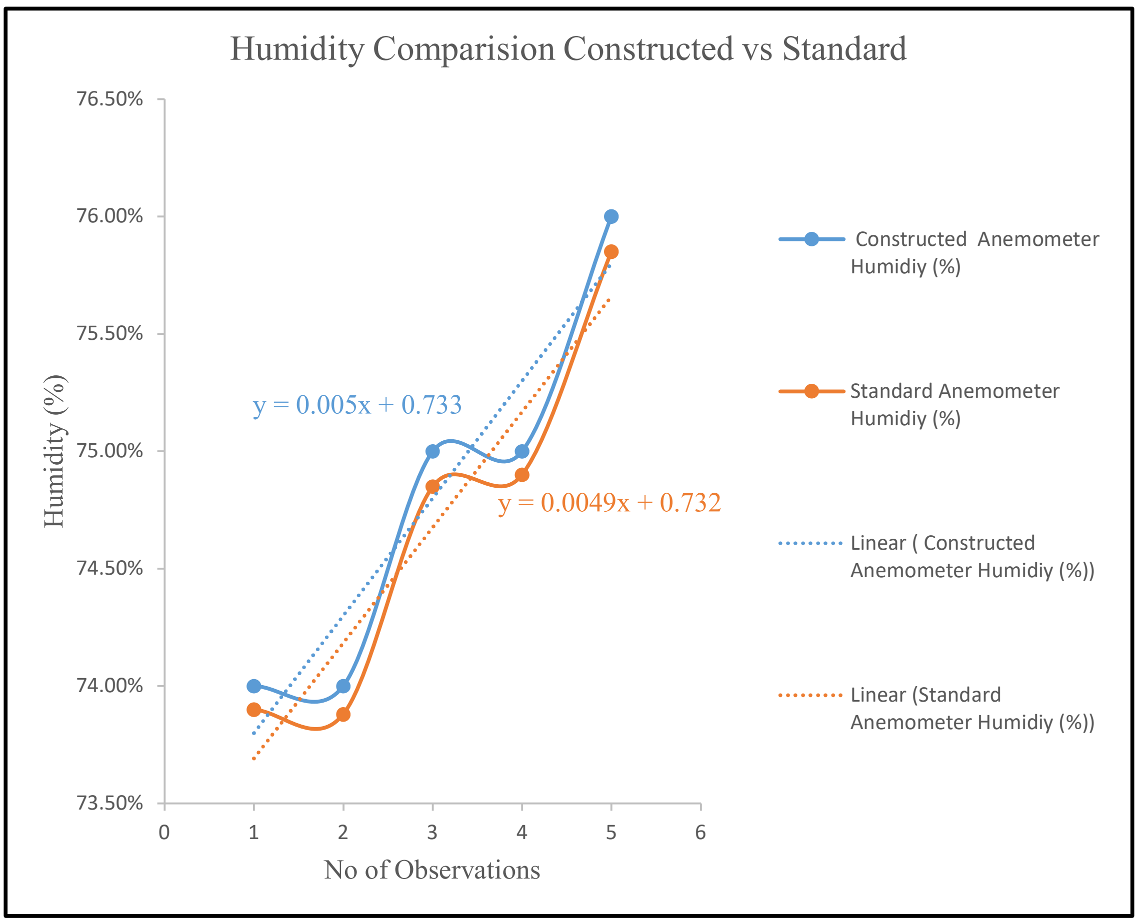

Figure 22: Humidity Comparison Constructed vs Standard.

5.3 Temperature Comparison between Constructed and Standard Anemometer

Table 3: Experimental data of temperature for constructed and standard anemometer.

No Of Observation	Constructed Anemometer	Standard Anemometer
	Temperature (℃)	Temperature (℃)
1	25	25
2	25.5	25.6
3	25.4	25.5
4	25.6	25.5
5	25.7	25.8

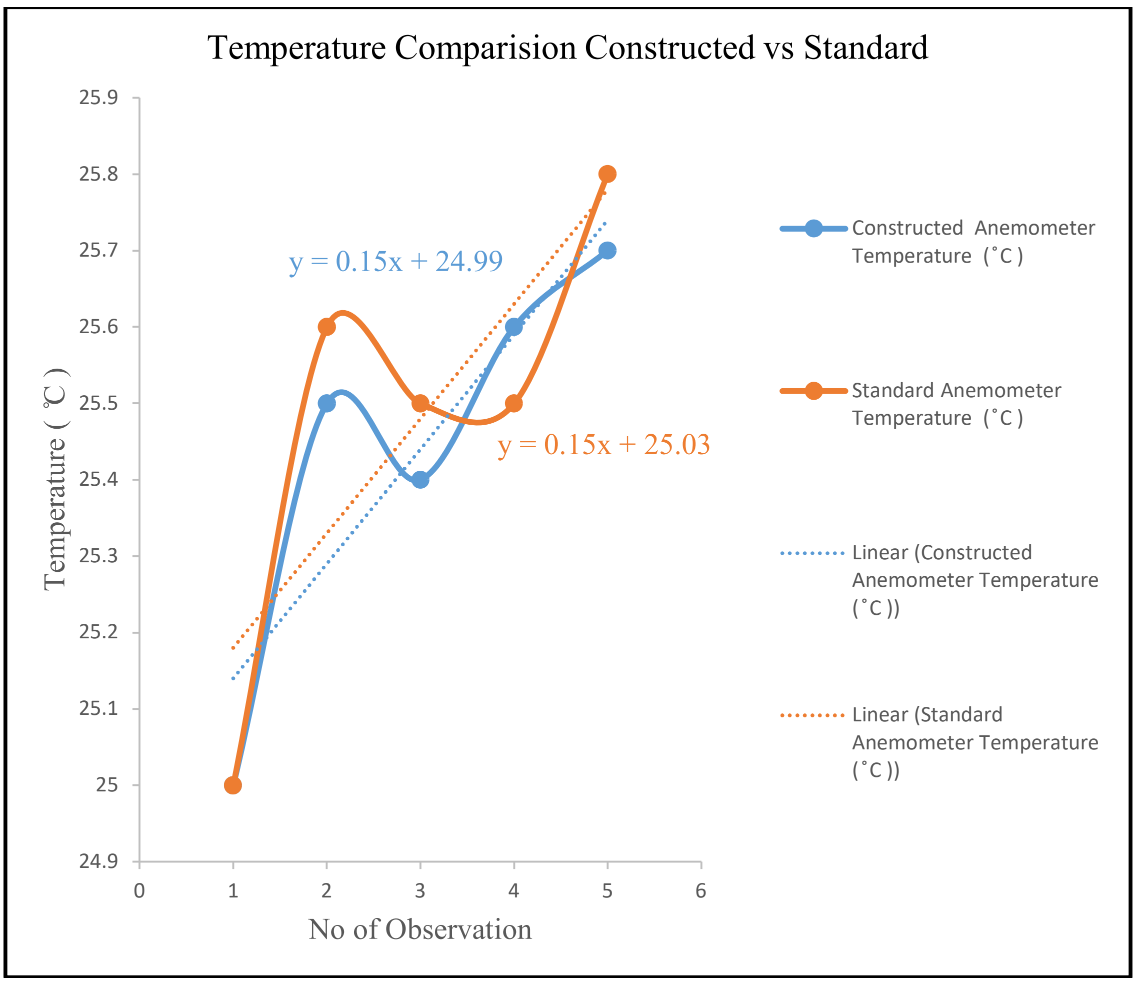

Figure 23: Temperature Comparison Constructed vs Standard.

5.4 Experimental Result of Wind Speed

1. $$\text{Error} = \left| \frac{\text{Standard - Constructed}}{\text{Standard}} \right| \times 100\%$$

$$= \left| \frac{3.02 - 3.12}{3.02} \right| \times 100\%$$

$$= -0.033\%$$

2. Accuracy = (100 - Error)

   = (100 – 0.033)

   = 99.967%

5.5 Experimental Result of Humidity

1. $$\text{Error} = \left| \frac{\text{Standard - Constructed}}{\text{Standard}} \right| \times 100\%$$

$$= \left| \frac{1.382 - 1.388}{1.382} \right| \times 100\%$$

$$= -0.004\%$$

2. Accuracy = (100 - Error)

   = (100 – 0.004)

   = 99.996%

5.6 Experimental Result of Temperature

3. $$\text{Error} = \left| \frac{\text{Standard - Constructed}}{\text{Standard}} \right| \times 100\%$$

$$= \left| \frac{25.48 - 25.44}{25.48} \right| \times 100\%$$

$$= 0.001\%$$

4. Accuracy = (100 - Error)

   = (100 – 0.001)

   = 99.999%

5.7 Discussion

The results show that the calibrated anemometer operates well within reasonable meteorological measurement accuracy criteria. The tiny variations in humidity and wind speed readings that have been noticed are negligible and have little effect on the device's overall dependability. Moreover, the data acquired are deemed reliable due to their continuous alignment with the standard calibration of the digital anemometer.

Chapter 6 Conclusion and Future Recommendations

6.1 Conclusion

We conclude that the calibrated anemometer satisfies the requirements for satisfactory accuracy based on the examination of temperature, humidity, and wind speed data. When compared to a conventional digital anemometer, its performance shows dependability in gathering meteorological data. These results confirm that the anemometer is appropriate for a range of environmental monitoring applications.

In general, the assessment affirms that the tested anemometer can be used as a dependable instrument to measure temperature, humidity, and wind speed, thereby advancing meteorological research and applications.

6.2 Future Recommendations

For future research on digital anemometers, several enhancements could be considered:

i. Add directional information parameter.
ii. Incorporate air density and pressure measurements.
iii. Introduce air movement angle measurement for enhanced analysis.

Chapter 7 References

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