Report

Of

Mini-Project Titled:

"Design and Analysis of true bladeless Airflow Generation System"

Submitted by

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1.Abstract:

The proposed mini-project aims to explore the design and analysis of a true bladeless airflow generation system based on the concept of ionic wind. Ionic wind, also known as corona discharge, is a phenomenon that occurs when a high voltage is applied between two electrodes, creating a stream of ionized air particles that can be directed to produce airflow. Unlike conventional fans, this technology offers a silent, energy-efficient, and low-maintenance solution for air circulation.

The project will involve a comprehensive study of the underlying principles of ionic wind, followed by the design and development of a prototype devices. Experimental testing will be conducted to analyse the airflow characteristics, velocity profiles, and energy efficiency of the system. The project will also investigate the potential applications of this technology in various domains, such as personal cooling, indoor air circulation, and industrial ventilation systems.

2.Introduction:

The quest for innovative and energy-efficient cooling solutions has led researchers to explore alternatives to conventional bladed fans and air conditioning systems. One promising technology that has garnered significant attention is the concept of ionic wind, also known as corona discharge. This phenomenon occurs when a high voltage is applied between two electrodes, creating a stream of ionized air particles that can be directed to produce airflow. Unlike traditional fans that rely on rotating blades, ionic wind technology operates on the principle of electrostatic forces, offering a unique and potentially groundbreaking approach to air circulation.

This mini-project aims to design and analyse a true bladeless airflow generation system based on the ionic wind concept. By harnessing this technology, the project seeks to develop a silent, energy-efficient, and low-maintenance solution for air circulation that could revolutionize personal cooling, indoor ventilation, and industrial applications. The project will commence with a comprehensive study of the underlying principles of ionic wind, delving into the fundamental physics and electrostatic mechanisms that govern this phenomenon.

Subsequent phases will involve the design and development of a prototype device, incorporating innovative electrode configurations and high-voltage circuitry to optimize airflow generation. The experimental testing will be conducted to analyse the airflow characteristics, velocity profiles, and energy efficiency of the system. The project will also explore potential applications and scalability of this technology, paving the way for its integration into various domains, contributing to a more sustainable and comfortable living environment.

3.Literature Survey:

The concept of ionic wind, also known as corona discharge, has been a subject of scientific inquiry for over a century. Early investigations into this phenomenon date back to the late 19th century, when researchers such as Townsend and Zeleny studied the movement of ionized air particles under the influence of electric fields. [1]

In the 1960s, significant advancements were made in understanding the underlying principles of ionic wind. Researchers like Stuetzer and Vellekoop conducted pioneering studies on the mechanisms of corona discharge and the resulting airflow patterns. Their work laid the foundation for exploring potential applications of this technology in various fields. [2][3]

With the rise of computational fluid dynamics (CFD) simulations in the late 20th century, researchers gained new tools to analyze and optimize ionic wind systems. Studies by Chattock and Trottier investigated the influence of electrode geometry, voltage potentials, and ion mobility on airflow characteristics. [4][5]

In recent years, the pursuit of energy-efficient and sustainable cooling solutions has fueled renewed interest in ionic wind technology. Researchers have explored innovative electrode configurations, high-voltage circuitry designs, and materials to enhance airflow generation and energy efficiency. [6][7]

Notable contributions in this field include the work of Hagopian et al., who developed a bladeless fan prototype based on ionic wind principles. Their research focused on optimizing electrode geometries and voltage potentials to maximize airflow velocity and efficiency. [8]

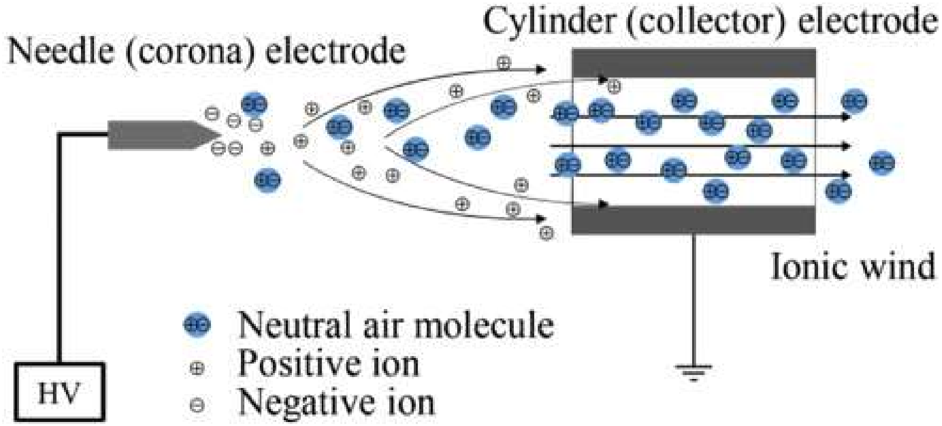
Seppey et al. investigated the scalability of ionic wind systems for industrial applications, exploring the potential for large-scale ventilation and cooling solutions. Their work highlighted the challenges associated with achieving uniform airflow distribution and addressed strategies to overcome them. [9]

Researchers have also explored the integration of ionic wind technology with other cooling systems, such as heat sinks and thermoelectric coolers. These hybrid approaches aim to leverage the advantages of ionic wind while mitigating potential limitations, such as ozone generation and ion deposition. [10][11]

Furthermore, studies have been conducted to assess the environmental impact and safety considerations of ionic wind systems, particularly regarding ozone production and electromagnetic compatibility. Efforts have been made to develop mitigation strategies and design guidelines to ensure safe and sustainable operation. [12][13]

4.Methodology

4.1 Ionic Wind:

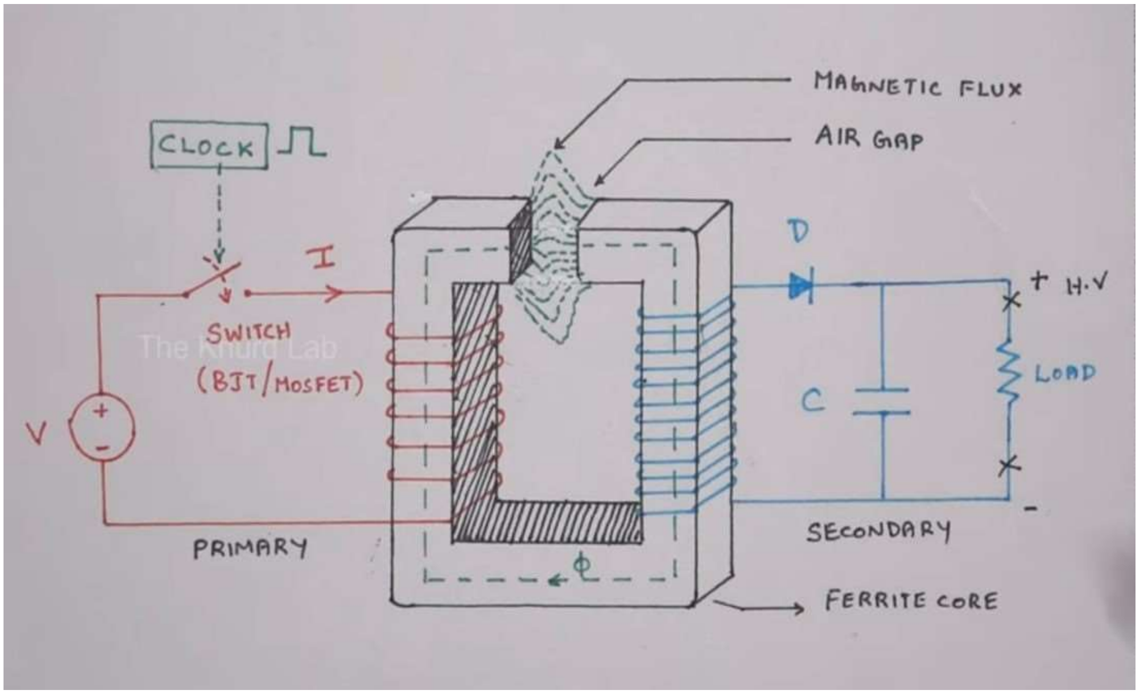


Ionic wind, also known as corona discharge, is a phenomenon that occurs when a high voltage is applied between two electrodes, creating a stream of ionized air particles that can be directed to produce airflow. This principle relies on the concept of electrostatic forces, where ions generated by the corona discharge are accelerated by the electric field, transferring their momentum to neutral air molecules, resulting in a directed airflow.

The ionic wind phenomenon involves several key processes: ionization of air molecules, ion acceleration, ion-neutral charge transfer, and momentum transfer. When a sufficiently high voltage is applied between the electrodes, the air molecules in the vicinity of the sharp electrode (emitter) are ionized, creating positively charged ions. These ions are then accelerated towards the opposite electrode (collector) due to the electric field, colliding with neutral air molecules along the way.

Through these collisions, the ions transfer their momentum to the neutral air molecules, setting them in motion and creating a directed airflow. The intensity and velocity of the airflow generated by ionic wind depend on various factors, including the applied voltage, electrode geometry, air density, and ion mobility. This technology offers a unique approach to air circulation, promising silent operation, reduced mechanical complexity, and potential energy savings compared to traditional bladed fans.

4.2 High Voltage Generator using flyback transformer:



Components:

1.Flyback Transformer:

a) Ferrite Core: Made of a material with high permeability, allowing it to efficiently concentrate magnetic flux lines. This concentrated flux is essential for high voltage generation.
b) Primary Coil: Insulated wire wrapped around the core. Current flowing through this coil creates the magnetic field.
c) Secondary Coil: Another insulated wire wrapped around the same core, but with a different number of turns compared to the primary coil. This is where the high voltage is induced.
d) Air Gap: A small intentional break in the ferrite core. This air gap plays a crucial role in generating the high voltage.

2.MOSFET (Metal-Oxide-Semiconductor Field-Effect Transistor):

Acts as a high-speed electronic switch, controlling the current flow through the primary coil.

Working:

1.Charging Phase (MOSFET On):

• When the MOSFET is turned on, current flows through the primary winding of the transformer.

• This current creates a magnetic field that gets concentrated by the ferrite core.

• The magnetic field strength increases as long as the current flows, proportional to the current and the number of turns in the primary winding.

• Energy is stored in the form of a magnetic field within the ferrite core.

2.Discharging Phase (MOSFET Off):

• When the MOSFET is turned off, the current flow in the primary winding abruptly stops.

• Due to the air gap in the core, the magnetic field cannot collapse instantaneously.

• The collapsing magnetic field induces a high voltage across the secondary winding according to Faraday's Law of electromagnetic induction.

• The induced voltage is proportional to the rate of change of the magnetic field and the number of turns in the secondary winding.

3.Open Secondary Circuit for Maximum Voltage:

• To maximize the induced voltage on the secondary side, the secondary circuit is often left open-circuited (no current flows in the secondary).

• Since energy needs to be conserved, the collapsing magnetic field induces a very high voltage on the secondary side to compensate for the lack of current flow.

• This principle relies on the law of conservation of energy.

Operation Summary:

The MOSFET and flyback transformer work together in a cycle:

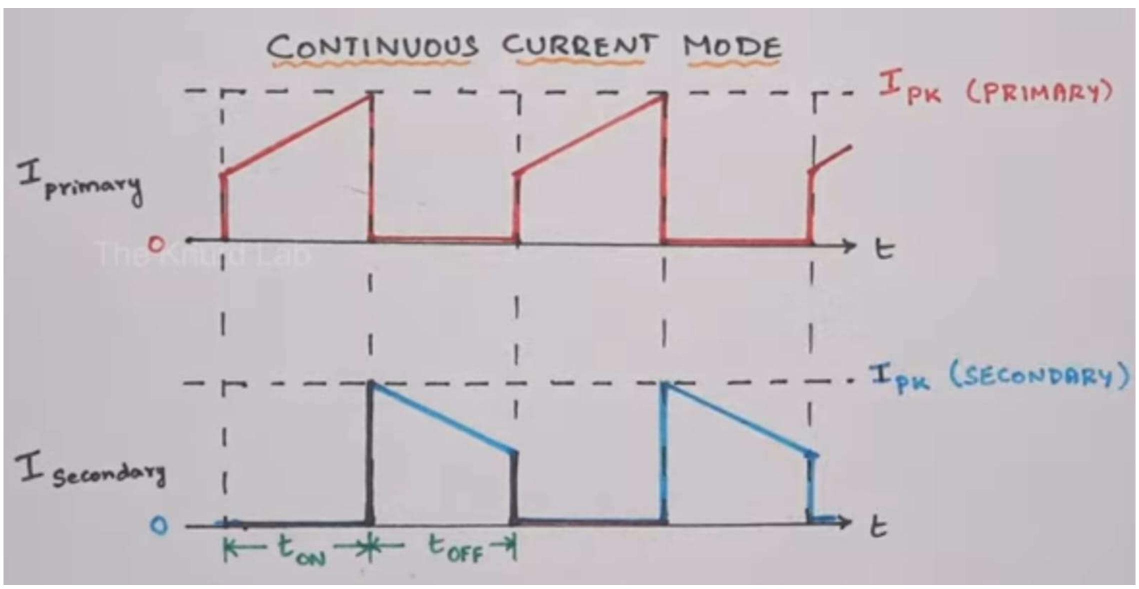
• During the "on" state of the MOSFET, energy is stored in the form of a magnetic field within the ferrite core.

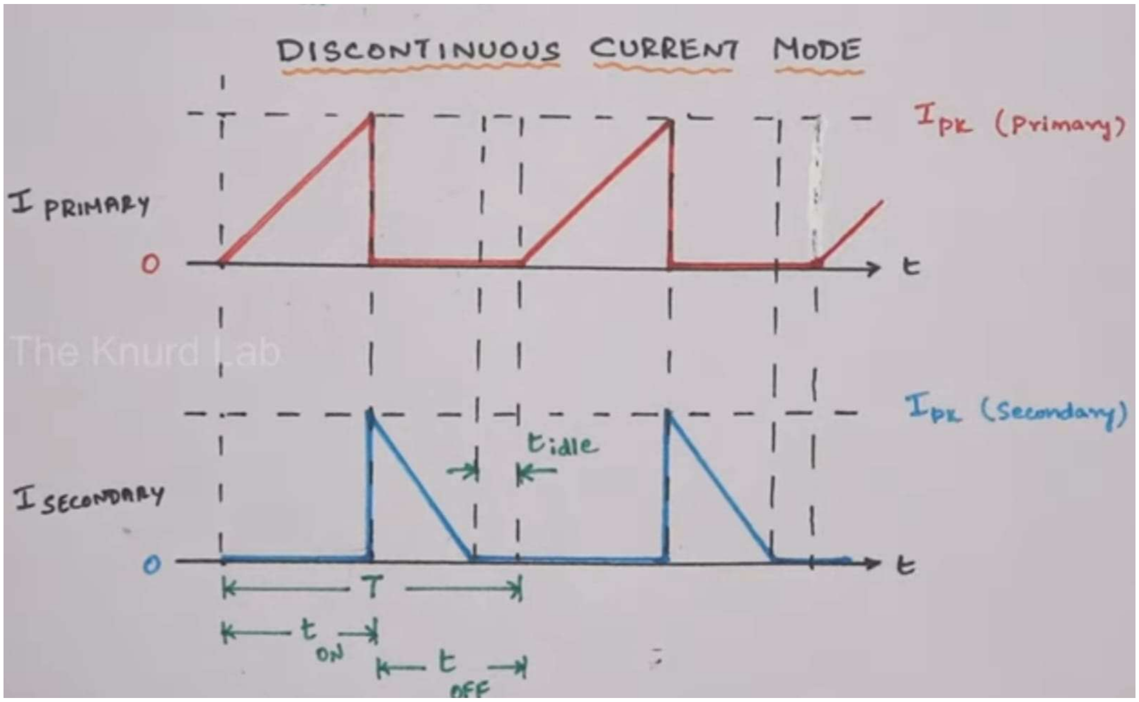
• When the MOSFET turns off, the stored magnetic field rapidly collapses due to the air gap, inducing a high-voltage pulse across the secondary winding.

• The high-voltage pulse is generated during the "off" state of the MOSFET, and the cycle repeats for continuous high-voltage generation.

The air gap in the core, the turns ratio between the primary and secondary windings, and the rate of change of the magnetic field determine the magnitude of the high voltage generated on the secondary side.

Waveforms of current in primary and Secondary:




DISCONTINUOUS CURRENT MODE
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OFF

4.3 Airflow Measurement:

The working principle of a digital anemometer based on an IR module for airflow measurement :

The anemometer consists of a lightweight vane or propeller that rotates when exposed to airflow. Attached to the rotating shaft is a disc or pattern with alternating opaque and transparent sections.

An IR (infrared) transmitter and receiver module are positioned on opposite sides of the rotating disc or pattern. The IR transmitter continuously emits an infrared beam towards the receiver.

As the disc or pattern rotates due to the airflow, it alternately blocks and allows the IR beam to pass through, creating a series of pulses at the IR receiver.

The IR receiver detects these pulses and sends them to a microcontroller or digital circuitry. The microcontroller counts the number of pulses received over a fixed time interval.

The number of pulses counted is directly proportional to the rotational speed of the vane or propeller, which in turn is directly related to the airflow velocity.

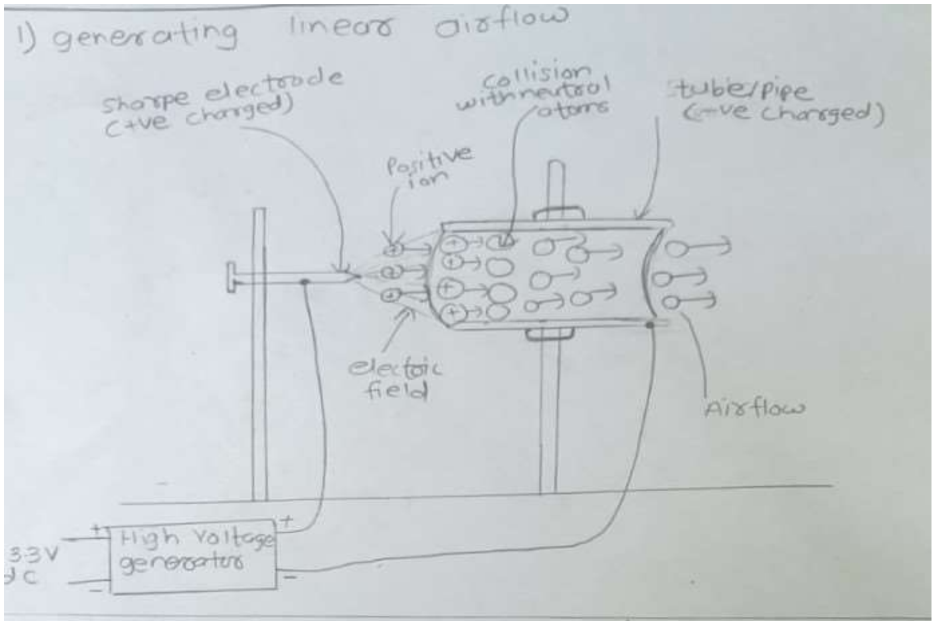
Using predetermined calibration factors specific to the anemometer's design, the microcontroller converts the rotational speed (derived from the pulse count) into the corresponding airflow velocity value.

This calculated airflow velocity value is then displayed on a digital readout or transmitted to a data acquisition system for further analysis or recording.

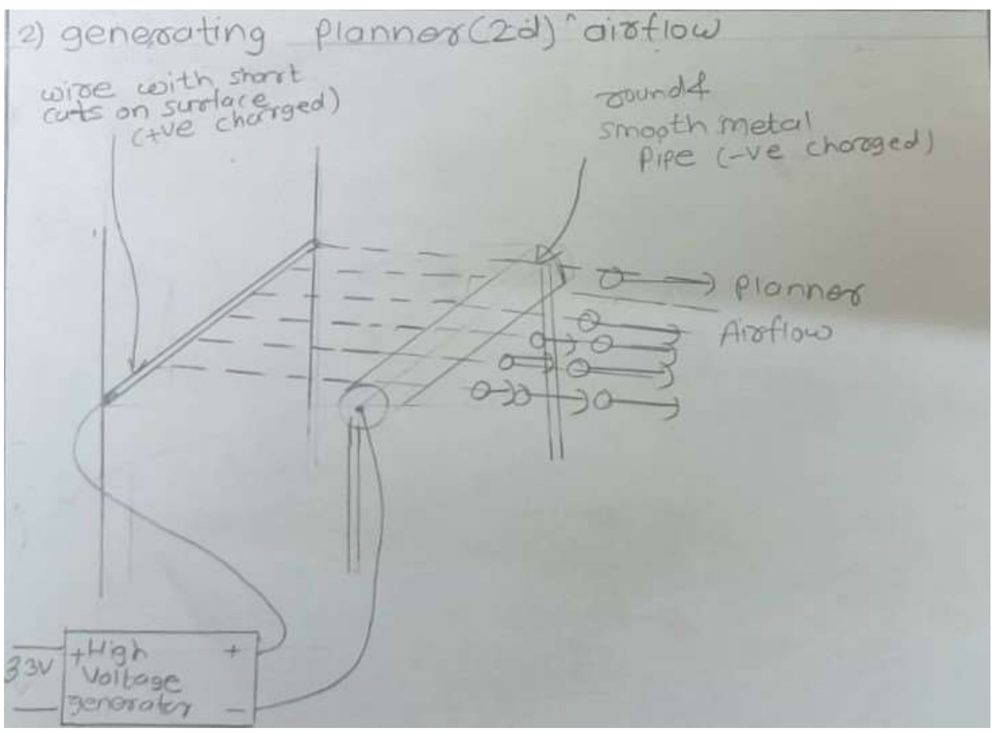
The working principle relies on the fact that the faster the airflow, the higher the rotational speed of the vane or propeller, and consequently, the higher the frequency of pulses generated by the IR module as the disc or pattern rotates.

5.Block Diagrams:

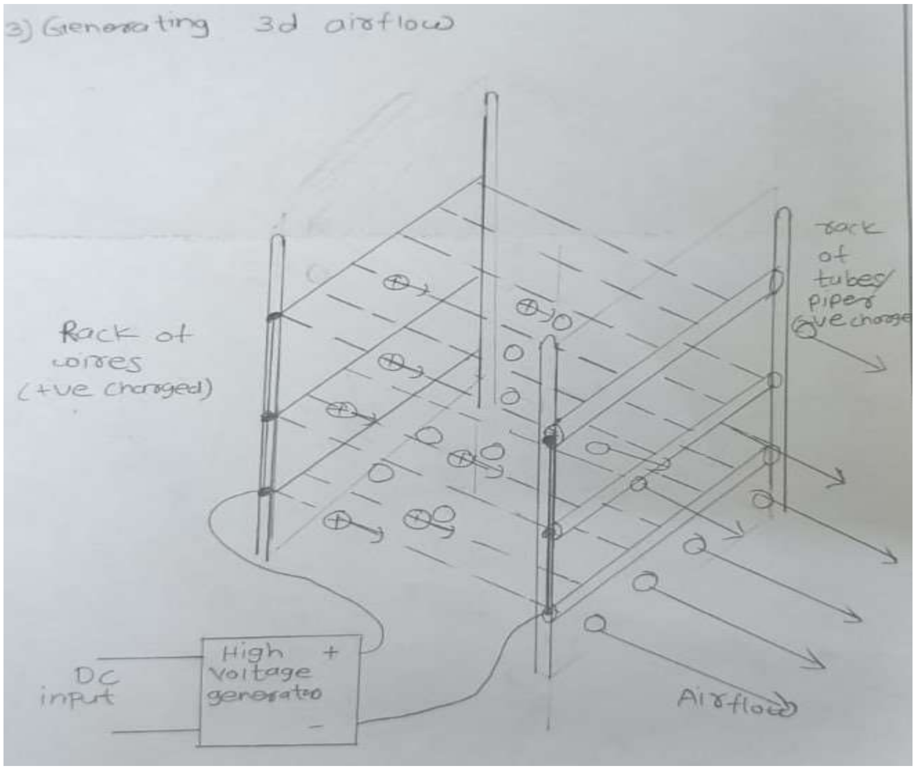
1)Prototype 1: Airflow Generation using point source



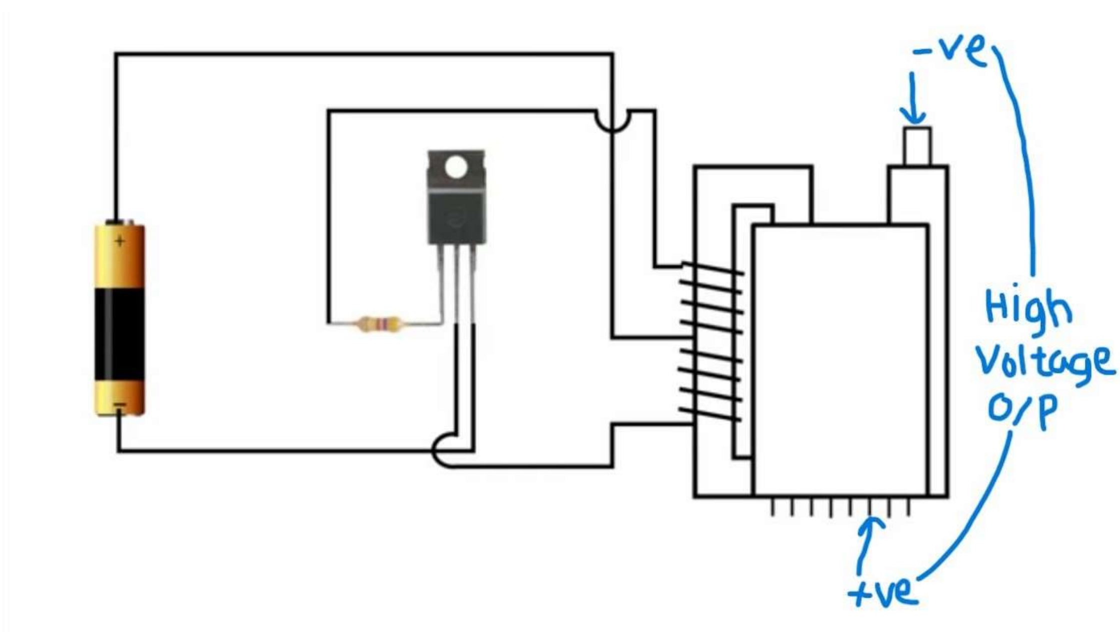
2)Prototype 2: Airflow Generation using wire as source



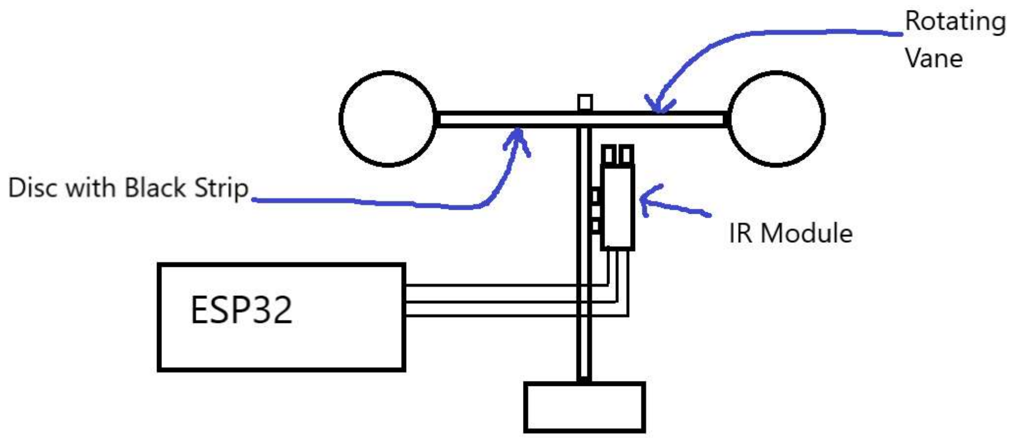
3)Prototype 3: Airflow generation using multiple stacked wires as source



High voltage generator using flyback transformer:

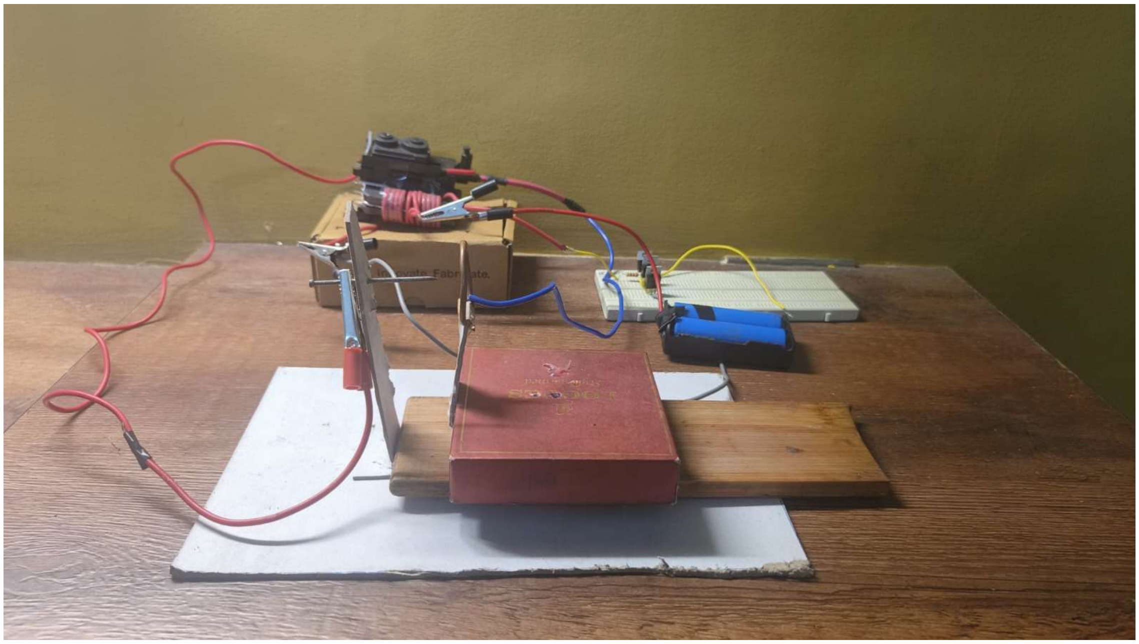


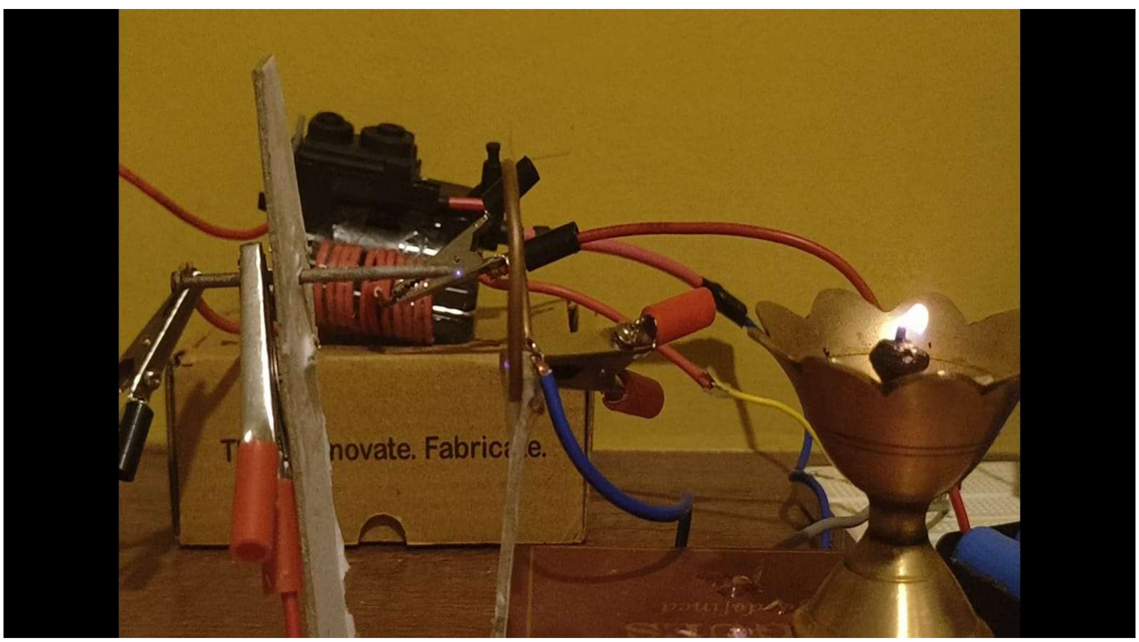
Digital Anemometer using IR Module:



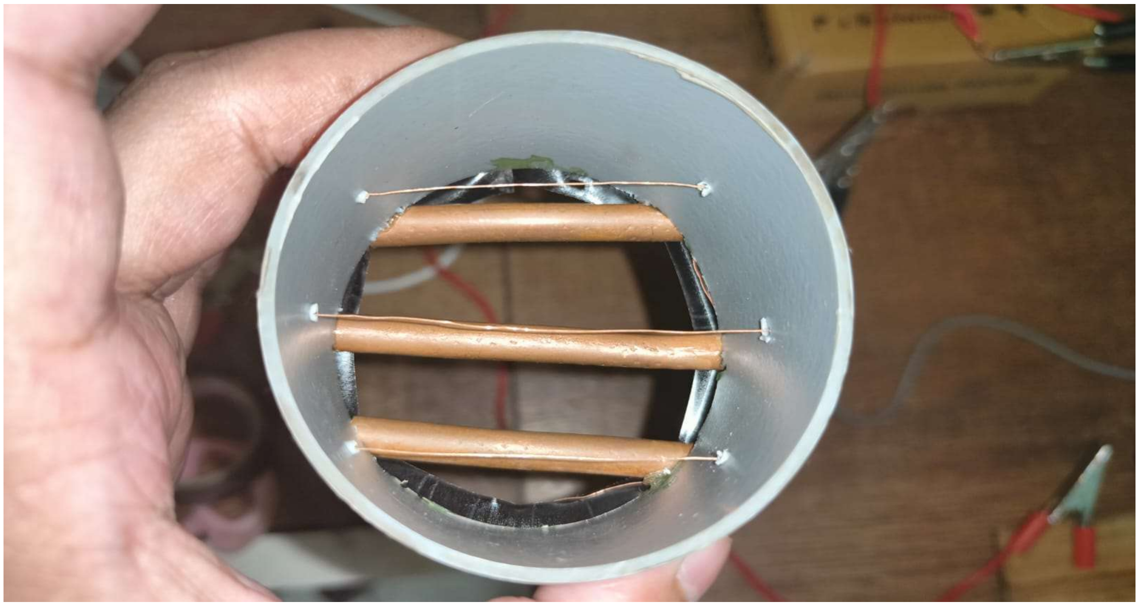
6.Project Photos:

Airflow Generation using point source

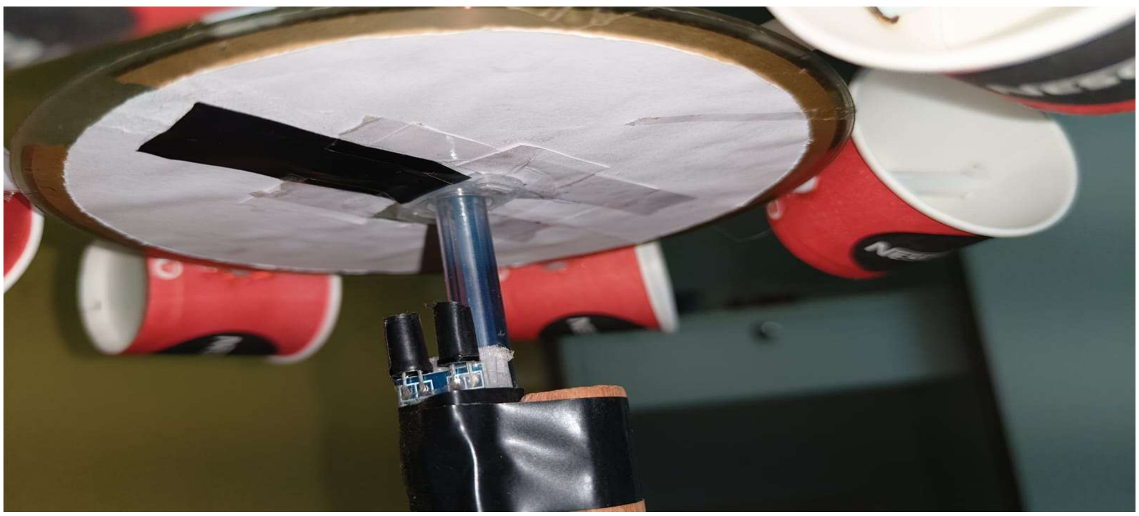


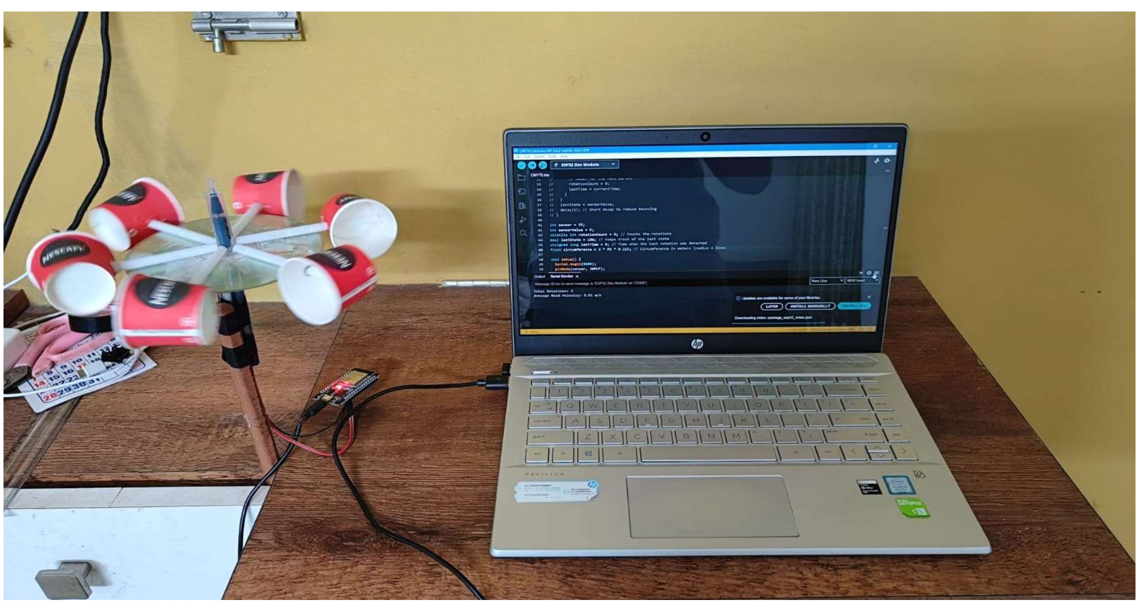


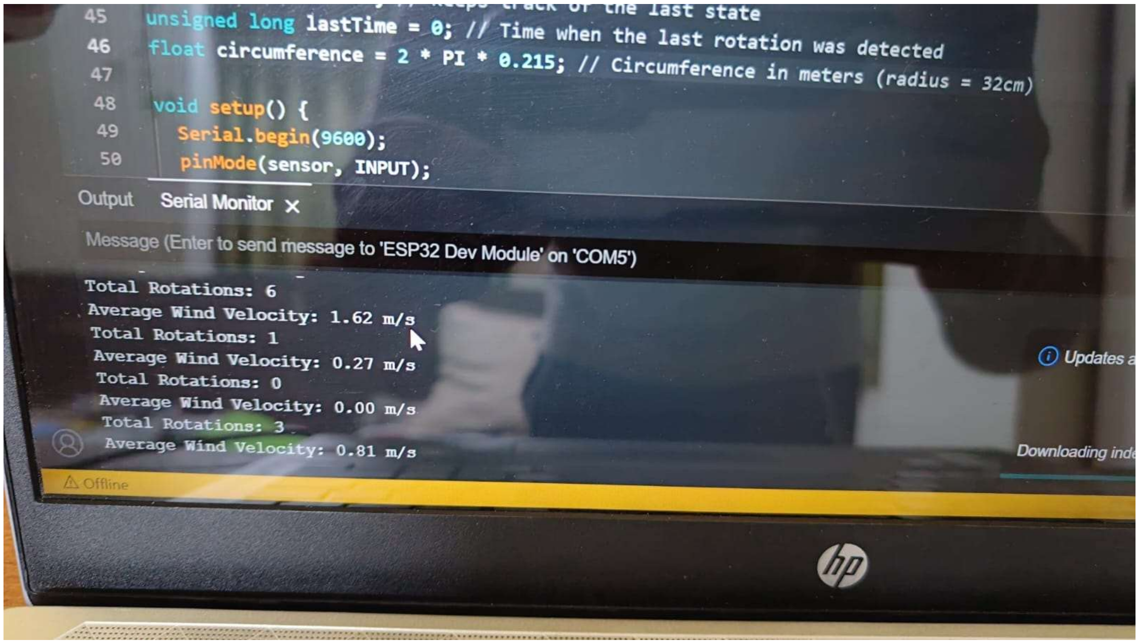
Airflow generation using multiple stacked wires as source



Digital Anemometer using IR module






unsigned long lastTime = 0; // Time when the last rotation was detected
float circumference = 2 * PI * 0.215; // Circumference in meters (radius = 32cm)
void setup() {
Serial.begin(9600);
pinMode(sensor, INPUT);
Output
Serial Monitor
Message (Enter to send message to 'ESP32 Dev Module' on 'COM5')
Total Rotations: 6
Average Wind Velocity: 1.62 m/s
Total Rotations: 1
Average Wind Velocity: 0.27 m/s
Total Rotations: 0
Average Wind Velocity: 0.00 m/s
Total Rotations: 3
Average Wind Velocity: 0.81 m/s
Offline

7.Conclusion:

In conclusion, the mini project on the Design and Analysis of a True Bladeless Airflow Generation System has successfully demonstrated the variability and controllability of airflow characteristics based on the configuration of the discharge source. The research highlighted two primary configurations: using a point as a source of discharge and employing stacked wires. The pointed discharge source results in airflow that is concentrated and highly localized, offering high velocity but limited in the area of effect. This makes it suitable for applications requiring intense, focused air delivery. Conversely, using stacked wires as a source of discharge distributes the airflow over a wider area with a reduction in velocity, which is ideal for applications needing gentle, dispersed air delivery, such as environmental conditioning in larger spaces.

Additionally, the project has shown that the rate of airflow can be effectively modulated by adjusting both the distance between the electrodes and the voltage applied. This degree of control allows the system to be tailored to specific needs and conditions, enhancing its utility across various applications.

Various designs of the discharge sources were also analyzed, each exhibiting distinct airflow characteristics. This variability underscores the potential for customizing the system to meet diverse application requirements, from industrial uses requiring robust air movement to subtle air circulation in residential settings.

However, a notable disadvantage of the system is the generation of ozone, which is a common issue with electrostatic and ionizing air systems. To mitigate this, several techniques can be employed:

1. Catalytic converters: These can break down ozone back into oxygen as air passes through the system.

2. Carbon filters: Incorporating activated carbon filters can help absorb ozone before the air is expelled.

3. Material choice: Using materials that reduce the generation of ozone at the source or prevent its emission into the environment.

4. Shielding and containment: Designing the system to contain and neutralize ozone within the unit before releasing air into the surrounding environment.

Employing these techniques can reduce the ozone output, making the bladeless airflow generation system safer and more environmentally friendly. Future studies could focus on refining these mitigation strategies and exploring additional design variations to enhance system performance and safety. The findings from this project pave the way for further innovation in bladeless air movement technology, offering promising directions for both industrial and consumer applications.

8.References:

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9.Appendix

Airflow Measurement using IR Module and ESP32 Code

```
int sensor = 35;
int sensorValue = 0;
volatile int rotationCount = 0; // Counts the rotations
bool lastState = LOW; // Keeps track of the last state
unsigned long lastTime = 0; // Time when the last rotation was detected
float circumference = 2 * PI * 0.215; // Circumference in meters (radius = 32cm)

void setup() {
  Serial.begin(9600);
  pinMode(sensor, INPUT);
  lastTime = millis(); // Initialize lastTime with the current time
}

void loop() {
  sensorValue = digitalRead(sensor);
  if (sensorValue && !lastState) {
    rotationCount++; // Increment rotation count
  }
  lastState = sensorValue;

  unsigned long currentTime = millis();
  float elapsedTime = (currentTime - lastTime) / 1000.0; // Elapsed time in seconds

  if (elapsedTime >= 5.0) { // Check every 5 seconds
```

```
    float distance = rotationCount * circumference; // Total distance traveled in meters
    float velocity = distance / elapsedTime; // Velocity in m/s

    Serial.print("Total Rotations: ");
    Serial.println(rotationCount);
    Serial.print("Average Wind Velocity: ");
    Serial.print(velocity);
    Serial.println(" m/s");

    // Reset for the next period
    rotationCount = 0;
    lastTime = currentTime;
  }

  delay(1); // Short delay to reduce bouncing
}
```