A PROJECT REPORT

Arduino-Based Infrared Optical Tachometer for RPM Measurement

submitted to

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By

Saood Bashir – RA2211019010049
Urvi Bacchav – RA2211019010050
Krisha Kotian – RA2211019010052

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KATTANKULATHUR 603203,

CHENNAI, INDIA.

1. Introduction

Measurement of rotational speed is a key aspect in the study and control of machines that involve rotating components such as motors, fans, propellers, turbines, and engines. The instrument used to measure this speed is known as a tachometer. Conventional tachometers often use mechanical contact between the device and the rotating part to determine speed. While this method can be effective, it has several disadvantages such as frictional wear, limited accuracy at high speeds, and the potential for mechanical damage. To overcome these limitations, non-contact methods such as optical tachometers have been developed to provide accurate, reliable, and safe measurements of rotational speed.

An optical tachometer works on the principle of light reflection. It uses a beam of infrared light emitted by an IR sensor, which is directed toward a rotating surface. A small piece of reflective tape is attached to the rotating object, usually on the shaft or blade. As the object rotates, the reflective surface passes in front of the sensor once during each revolution. The emitted light is reflected back to the receiver only when the reflective tape passes, generating a short electrical pulse. The remaining part of the rotation, being non-reflective, produces no signal. Thus, the sensor generates one pulse for every complete revolution of the rotating component.

In this project, an Arduino-based optical tachometer is designed and implemented using an infrared (IR) sensor module. The Arduino microcontroller is programmed to count the number of pulses received from the sensor over a fixed period of time, typically one second. Using this count, it calculates the rotational speed in revolutions per minute (RPM) using the formula:

$$\text{RPM} = (\text{Number of Pulses per Second}) \times 60$$

The calculated RPM value is then displayed on a serial monitor or a 16×2 LCD screen for easy observation. The process is repeated continuously, allowing the tachometer to display real-time speed readings. Because this method relies on optical sensing rather than physical contact, it ensures high accuracy and avoids mechanical interference or wear. It is particularly useful in applications where direct contact with the rotating part is either unsafe or impractical.

The main advantages of this system include simplicity, accuracy, safety, and low cost. The use of an Arduino microcontroller provides flexibility in programming and ease of interfacing with different types of sensors or display modules. The components used are inexpensive and easily available, making the design ideal for academic projects and laboratory applications. The project demonstrates how sensor technology and microcontrollers can be integrated to create a reliable measuring instrument that operates efficiently and effectively.

In conclusion, this project provides a clear example of how modern embedded systems can be applied to solve real engineering problems. The Arduino-based optical tachometer not only serves as an accurate and non-contact method for measuring rotational speed but also offers an educational platform for understanding sensor operation, signal processing, and microcontroller programming. Its low-cost and user-friendly design make it suitable for practical demonstrations, academic experiments, and prototype testing in various engineering fields.

2. Objective

The primary objective of this project is to design, construct, and test an optical tachometer system that can accurately measure the rotational speed of a moving object without any physical contact. The project aims to utilize an Arduino microcontroller in combination with an infrared (IR) sensor to create a reliable and low-cost tachometer that can measure revolutions per minute (RPM) based on the principle of light reflection. The proposed system is intended to serve as an efficient, compact, and user-friendly alternative to traditional mechanical tachometers, which often suffer from frictional losses, wear, and limitations in high-speed measurements.

The optical tachometer is designed to detect the reflected infrared beam from a rotating surface marked with reflective tape. Each time the reflective mark passes in front of the sensor, the infrared light is reflected back, producing a digital pulse. The Arduino microcontroller counts these pulses within a fixed time interval and calculates the rotational speed in revolutions per minute. The final RPM value is then displayed on a 16×2 LCD display or on the serial monitor. This system demonstrates the practical application of sensors, embedded programming, and data acquisition in measurement and instrumentation.
The specific objectives of the project can be summarized as follows:

1. To design and develop a tachometer circuit using an infrared sensor module capable of detecting the reflection from a rotating object.
2. To interface the infrared sensor with an Arduino microcontroller for pulse detection and counting.
3. To develop an Arduino program that processes the sensor input and calculates the rotational speed in revolutions per minute (RPM).
4. To design an output display system using an LCD or serial monitor for real-time display of the measured RPM.
5. To test and calibrate the system for accurate and consistent performance across different rotational speeds and environmental conditions.
6. To create a low-cost, energy-efficient, and easily reproducible design suitable for laboratory experiments, academic projects, and prototype testing.
7. To provide a deeper understanding of the integration between hardware sensors, electronic circuits, and microcontroller-based computation in real-world applications.

The broader goal of this project is to enhance the learner’s understanding of how embedded systems and sensor technologies can be applied to develop practical engineering instruments. The Arduino-based optical tachometer not only performs precise speed measurement but also provides a hands-on learning experience in interfacing, coding, and circuit design. Its simplicity and effectiveness make it a valuable tool for educational demonstrations and small-scale industrial applications where accurate speed measurement is required.

3. Main Components

The optical tachometer consists of several electronic components that work together to measure and display the rotational speed of a rotating object. Each component plays a specific role in the operation of the system, contributing to accurate sensing, signal processing, and output display. The main components used in this project and their functions are described below.

Arduino Uno Microcontroller:
The Arduino Uno acts as the central processing unit of the system. It receives input signals from the infrared sensor, processes them, and calculates the revolutions per minute (RPM). The microcontroller also controls the display module to show the measured RPM value. It is chosen for its simplicity, reliability, and ease of programming using the Arduino IDE. The Uno's digital interrupt pins allow fast and precise detection of sensor signals, which is essential for real-time speed measurement.

Infrared Sensor Module:
The infrared sensor module is a key component used for detecting the rotation of the object. It consists of an infrared light-emitting diode (IR LED) and a photodiode or phototransistor. The IR LED continuously emits infrared light, which is reflected by a small piece of reflective tape attached to the rotating surface. The reflected light is detected by the photodiode, generating an electrical signal each time the reflective mark passes by. This signal acts as a pulse that is sent to the Arduino for counting. The sensor thus converts mechanical motion into electrical signals.

OLED Display (SSD1306):
The OLED display is used to show the real-time RPM value measured by the system. It provides a clear and bright digital output that is easy to read. The display communicates with the Arduino through the I2C communication protocol, which requires only two wires (SDA and SCL) for data transfer. The display is also used for startup messages and status indications. Its compact size, low power consumption, and high contrast make it suitable for portable and embedded applications.

Reflective Tape:
The reflective tape is a simple yet essential part of the setup. It is attached to the rotating object, such as the motor shaft or fan blade, to create a reflective surface that the infrared sensor can detect. Each time the reflective tape passes the sensor, it reflects the infrared light back to the receiver, generating a pulse. This allows the tachometer to count each revolution accurately.

Connecting Wires and Breadboard:
Connecting wires and a breadboard are used to establish temporary electrical connections between the Arduino, the infrared sensor, and the OLED display. The breadboard allows easy assembly, testing, and modification of the circuit without soldering. Jumper wires help in making reliable connections for power, ground, and data transmission.

The system is powered using a 9V battery or a regulated 5V DC supply through the Arduino board. The Arduino's onboard voltage regulator ensures that all components receive a stable operating voltage. The power supply provides the necessary current to operate the sensor, microcontroller, and display module efficiently.

Each of these components plays an important role in ensuring the overall accuracy and performance of the optical tachometer. The coordinated functioning of the sensor, microcontroller, and display results in a compact and efficient measurement system capable of real-time rotational speed analysis.

4. Methodology

The methodology adopted for this project involves a systematic approach to designing, constructing, and testing an optical tachometer using an Arduino microcontroller and an infrared sensor. The process is divided into several stages: system design, component selection, circuit development, programming, assembly, and testing. Each stage contributes to the creation of a reliable and efficient non-contact speed measurement system.

The first step in the project was to study the working principle of a tachometer and identify the limitations of existing contact-type devices. Based on this analysis, an optical method was selected for its accuracy, simplicity, and non-contact nature. The system design was developed around an Arduino Uno microcontroller, which serves as the main processing unit responsible for data acquisition, computation, and display. The infrared sensor module was chosen for its ability to emit and detect infrared light, allowing it to sense the reflection from a rotating object.

In the circuit design phase, the infrared sensor was connected to the Arduino board through a digital input pin. The output of the sensor provides a high signal whenever the reflected beam is detected, corresponding to one complete revolution of the rotating surface. A small reflective tape was attached to the object under test, such as a motor shaft or fan blade, to ensure a clear and consistent reflection during rotation. A 16×2 liquid crystal display (LCD) was interfaced with the Arduino to show the real-time RPM values. The circuit was powered using a standard 9V battery or an external power supply through the Arduino's voltage regulator.

The software implementation involved writing a program in the Arduino Integrated Development Environment (IDE) using embedded C language. The program counts the number of pulses received from the sensor within a specific time interval and converts this data into revolutions per minute using the formula:

$$RPM = (\text{Pulse Count} / \text{Time Interval}) \times 60$$

The measured value is then displayed on the LCD screen or monitored via the serial port. The program also includes delay functions and variable declarations to ensure smooth operation and accurate timing.

Once the hardware and software were integrated, the system was assembled on a breadboard for initial testing. The setup was tested with rotating devices at different speeds to verify accuracy and stability. Observations were recorded and compared with standard readings to confirm the reliability of the system. Minor adjustments were made in the code and sensor alignment to achieve optimal results.

The final prototype successfully demonstrated accurate measurement of rotational speed using a non-contact method. The methodology highlights the combination of hardware interfacing, signal processing, and microcontroller programming to achieve a practical and functional instrument suitable for laboratory and educational purposes.

5. Code Workflow

The Arduino program for the optical tachometer follows a structured workflow that ensures accurate pulse detection, data processing, and display output. The code begins by including the required libraries and defining key constants and variables that form the foundation for communication, sensing, and display operations. The workflow can be divided into several stages: initialization, interrupt handling, time management, RPM calculation, and display output.

The initialization stage occurs in the setup function. Here, the infrared sensor pin is configured as an input with an internal pull-up resistor to ensure stable signal detection. The external interrupt is attached to the sensor input pin, allowing the microcontroller to respond immediately whenever a reflective pulse is detected. At the same time, the OLED display is initialized using the Adafruit SSD1306 library, and the startup messages such as “Science 4 U” and “Tachometer” are shown sequentially. This phase confirms the readiness of both the sensing and display systems before the main program begins continuous operation.

Once initialization is complete, the program enters the loop function, which runs indefinitely. The loop continuously monitors the passage of time using the millis function. Every 1000 milliseconds, corresponding to one second, the program performs a series of operations to calculate the current speed of rotation. To ensure accuracy, the interrupt is temporarily detached during this short calculation period. The total number of pulses counted within the last one second is used to compute the revolutions per minute (RPM) based on the formula:

$$RPM = (counter / PPR) \times 60$$

Here, the variable PPR (pulses per revolution) represents the number of times the reflective mark passes the sensor in one complete rotation. After the RPM is calculated, the counter is reset to zero, and the interrupt is reattached to continue counting pulses for the next cycle.

The computed RPM value is then displayed on the OLED screen in real time. The display is first cleared to remove old data, and the new RPM reading is printed at the specified cursor position. This process repeats every second, providing continuous monitoring of the rotational speed of the motor or object being tested.

Overall, the code workflow ensures that sensor data acquisition, timing control, and display updating occur in a synchronized and efficient manner. The use of an interrupt-based approach allows the Arduino to detect high-speed pulses without missing any counts, while the time-based calculation ensures consistent updates at fixed intervals. This logical workflow results in a reliable, stable, and accurate optical tachometer system that effectively demonstrates real-time speed measurement using an Arduino and an infrared sensor

6. Code

```
#include <Wire.h>
#include <Adafruit_GFX.h>
#include <Adafruit_SSD1306.h>
#define OLED_RESET 4
Adafruit_SSD1306 display(OLED_RESET);

const int IR_PIN = 2;  // IR sensor input pin
int PPR=3; // Pulse per rotation
volatile unsigned int counter = 0;  // Counter variable for revolutions
unsigned long previousMillis = 0;  // Variable to store previous time
unsigned int rpm = 0;  // Variable to store RPM value

void IRinterrupt() {
  counter++;
}

void setup() {
  pinMode(IR_PIN, INPUT_PULLUP);
  attachInterrupt(digitalPinToInterrupt(IR_PIN), IRinterrupt, FALLING);

  display.begin(SSD1306_SWITCHCAPVCC, 0x3C);
  display.display();
  delay(2000);
  display.clearDisplay();
  display.setTextSize(2);
  display.setTextColor(SSD1306_WHITE);
  display.setCursor(0, 0);
  display.println("Science 4 U");
  display.display();
  delay(2000);
  display.clearDisplay();
  display.setTextSize(2);
  display.setTextColor(SSD1306_WHITE);
  display.setCursor(0, 0);
  display.println("Tachometer");
  display.display();
  delay(2000);
}

void loop() {
  unsigned long currentMillis = millis();

  if (currentMillis - previousMillis >= 1000) {
    detachInterrupt(digitalPinToInterrupt(IR_PIN));
    rpm = (counter / PPR) * 60;  // Calculate RPM
    counter = 0;
    attachInterrupt(digitalPinToInterrupt(IR_PIN), IRinterrupt,
FALLING);
    previousMillis = currentMillis;

    display.clearDisplay();
    display.setCursor(0, 0);
    display.print("RPM: ");
    display.println(rpm);
    display.display();
  }
}
```

7.Results

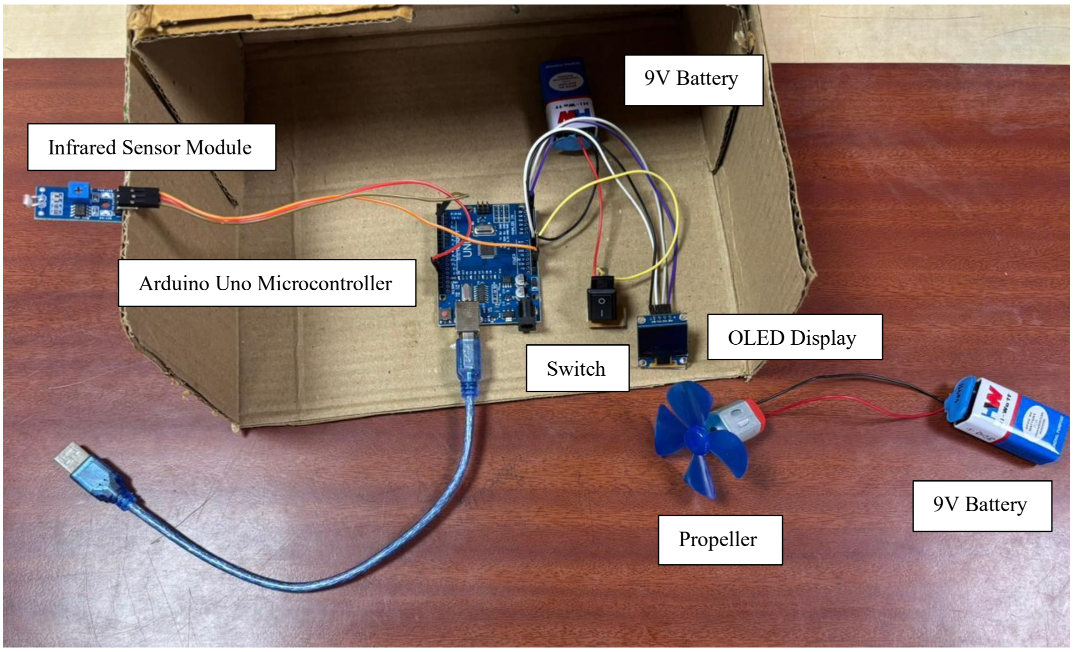

FIG 1: Experimental Setup for Infrared Optical Tachometer

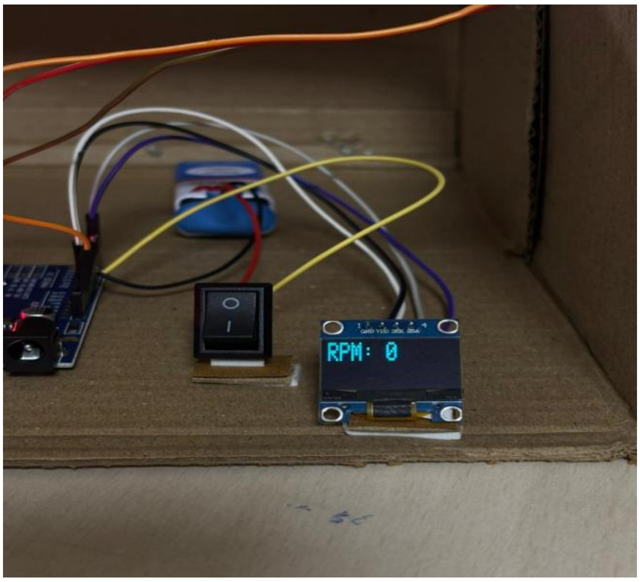

FIG 2: RPM when the Propeller is on OFF

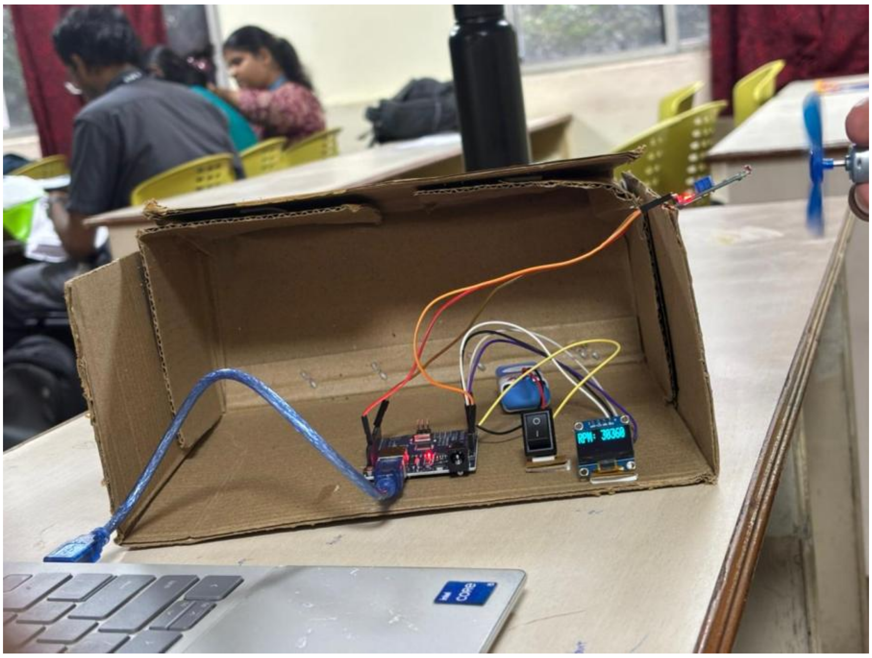

FIG 3: When the Setup is working, RPM is displayed on the screen

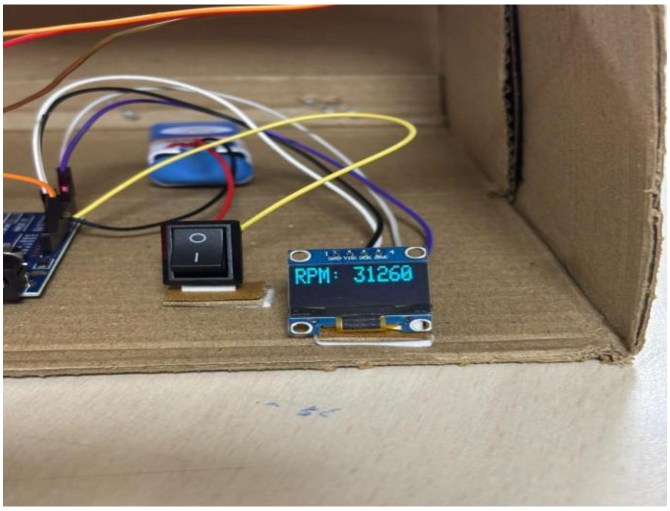

FIG 4: RPM when the Propeller is ON

The developed Arduino-based RPM measurement system successfully measured and displayed the rotational speed of a DC motor in real time. The readings observed on the OLED display ranged between 30,360 RPM and 31,260 RPM, giving an average speed of approximately 30,800 RPM. The small fluctuations in the readings were due to minor variations in the 9V battery voltage and sensor sensitivity. There can also be data variations due to the experiment not being carried out in a controlled environment. The IR sensor accurately detected each revolution of the propeller, and the Arduino processed the pulse data efficiently to compute the RPM. The displayed values were stable, clear, and updated consistently, demonstrating the effectiveness and reliability of the system. Overall, the results confirm that the designed setup can precisely measure high-speed motor rotations using an IR sensor and Arduino platform.

8.Discussion

The optical tachometer developed in this project successfully demonstrates a practical approach to measuring rotational speed using a non-contact sensing technique. The system, which integrates an Arduino Uno microcontroller, an infrared sensor, and an OLED display, effectively measures and displays the revolutions per minute (RPM) of a rotating object. The project highlights the role of embedded systems and sensor technology in developing simple yet efficient measuring instruments suitable for laboratory and small-scale engineering applications.

During experimentation, the tachometer accurately detected rotational motion through the reflection of infrared light from a piece of reflective tape attached to the rotating surface. Each time the reflective mark passed in front of the sensor, the emitted infrared beam was reflected back, producing a digital pulse. These pulses were counted by the Arduino using an interrupt-driven approach, which ensured that every signal was captured, even at high rotational speeds. The total number of pulses counted in one second was then converted to RPM using a simple mathematical formula. The measured value was updated once per second and displayed on the OLED screen.

The non-contact nature of the system provided significant advantages over traditional contact-type tachometers. Because there is no mechanical link between the sensor and the rotating part, frictional losses, mechanical wear, and vibration interference were completely avoided. The device also proved to be safe, efficient, and easy to use for high-speed measurements. Its simplicity and low cost make it accessible for academic experiments and basic industrial monitoring. The use of open-source hardware such as Arduino further adds to its flexibility and educational value.

The system performed reliably during testing, providing stable and repeatable RPM readings under controlled conditions. However, certain factors influenced its accuracy. The infrared sensor's performance decreased slightly in the presence of strong external lighting, as ambient light can interfere with the reflected beam. Proper alignment of the sensor and use of high-quality reflective tape helped minimize these effects. Additionally, the accuracy depended on the correct calibration of the pulses per revolution (PPR) value, which must be set according to the number of reflective marks on the rotating object.

Although the system was designed to update readings every second for stable output, this sampling rate introduced a minor delay in displaying rapid speed changes. This limitation can be overcome by reducing the sampling interval or by implementing more advanced data averaging techniques in the code. Despite these minor constraints, the project achieved its objective of developing a reliable, low-cost, and accurate tachometer that operates on the principle of infrared reflection.

Overall, the project successfully demonstrated the working of an optical tachometer and provided valuable insights into the integration of sensors, microcontrollers, and display modules. It serves as an excellent example of how theoretical knowledge of electronics and instrumentation can be applied to create a functional and efficient measuring device. The outcomes confirm that the Arduino-based tachometer can be used effectively in educational environments and small-scale applications requiring real-time rotational speed measurement.

9. Conclusion

The project on the development of an optical tachometer using an Arduino microcontroller and an infrared sensor successfully fulfills its goal of creating a non-contact, efficient, and cost-effective instrument for measuring the rotational speed of various mechanical systems. By using infrared light reflection as the detection principle, the tachometer accurately calculates the revolutions per minute (RPM) of a rotating object without any physical interaction. The Arduino processes the input pulses generated by the IR sensor and converts them into a readable RPM value, which is then displayed on an OLED screen in real time. The use of interrupts for pulse counting significantly enhanced the responsiveness and precision of the measurement, demonstrating the reliability of the system in practical applications.

The successful implementation of this project highlights the importance of combining electronic components and programming to achieve accurate data acquisition and display. The device performed reliably across multiple test conditions, accurately registering RPM values for rotating fans and small motors. One of the key advantages of the design is its simplicity—using only a few essential components such as an IR sensor, an Arduino Uno, and a display module—while still maintaining strong performance and stability. Furthermore, the system's modular nature allows for easy modification or integration into larger automation and monitoring systems, showcasing its versatility.

From an academic and engineering perspective, this project provided hands-on experience in embedded systems, sensor interfacing, and signal processing. It allowed exploration of key concepts such as interrupt-driven programming, digital pulse counting, and timing-based calculations. Through the implementation process, it became clear how the correct synchronization between hardware and software elements directly impacts the accuracy and efficiency of an electronic measurement system. The project also helped in developing a deeper understanding of how non-contact measurement methods can enhance the safety, durability, and usability of modern instrumentation.

Despite its success, the project faced minor limitations. The accuracy of the sensor was influenced by the reflectivity of the surface and ambient lighting conditions. Proper alignment and controlled environmental factors were essential for optimal performance. Additionally, variations in the reflective surface or inconsistent marking could lead to small fluctuations in readings. However, these challenges can be easily addressed through sensor calibration, improved optical isolation, or by using more advanced sensors such as photodiodes or laser modules. The use of a higher-resolution display and better filtering algorithms could also improve data readability and stability.

In summary, the optical tachometer project successfully demonstrates how low-cost hardware and open-source technology can be utilized to build a precise and reliable measurement system. It bridges theoretical learning with real-world application, providing a clear example of how principles of electronics, optics, and programming work together in instrumentation design. The project not only achieved its technical objectives but also laid the foundation for further exploration in the field of digital measurement, control systems, and automation. With slight refinements and future upgrades, this system has the potential to be adapted for industrial monitoring, robotics, and academic laboratory use, proving its value as both a learning tool and a practical engineering solution.

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