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Development of a Digital Tachometer Using Microcontroller and Optical Sensor

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ABSTRACT:
This paper presents the design and development of a digital tachometer using a microcontroller and an optical sensor to measure the rotational speed of rotating mechanical systems. Traditional tachometers rely on mechanical or electromagnetic principles that may introduce inaccuracies due to friction, wear, or electromagnetic interference. In contrast, an optical sensor-based system offers non-contact measurement, thereby improving precision and longevity. The integration of a microcontroller enables real-time processing of sensor signals, converting them into readable RPM values. The system used microcontroller to process the signals from the optical sensor. However, the system was calibrated using a known speed reference tested for accuracy. the result showed that the developed system achieved an accuracy of ± 1% and a resolution of 1.2 rpm. The developed system is efficient, low-cost, and applicable to a wide range of industrial and automotive applications.

KEYWORDS: Microcontroller, optical sensor, rotational speed, Liquid crystal display (LCD).

I. INTRODUCTION

Tachometers are essential and crucial devices for measuring the rotational speed of machinery, motors, and engines.[1,2] Accurate speed measurement is essential in various industries, including automotive, manufacturing, and aerospace, to monitor performance and ensure safety. Traditional tachometers, including analog and electromagnetic types, have limitations such as mechanical wear, susceptibility to interference, and difficulty in providing digital data for further processing.[4] The objectives are to design and develop a digital tachometer using a microcontroller (e.g., Arduino) and optical sensor (e.g. Infrared photodiode), investigate the performance of the developed tachometer in terms of accuracy, resolution, and reliability, comparing the result from traditional analog to digital tachometer and evaluating the feasibility of using the developed device in industrial applications.

In this paper, a digital tachometer based on a microcontroller and an optical sensor was developed. This system utilizes the non-contact principle of optical sensing to measure the rotational speed accurately. The microcontroller processes the data from the sensor and displays the revolutions per minute (RPM) on a digital screen. The designed system offers advantages such as high precision, low power consumption, and compatibility with digital interfaces for integration with other systems.

II. LITERATURE REVIEW

2.1 Traditional Tachometers

Conventional tachometers have been deployed for decades to measure out rotational speed. Analog tachometers often rely on mechanical mechanisms, such as spinning discs and magnets, which convert rotational motion into measurable outputs. [4]. While reliable, these devices face issues like wear and tear, frictional losses, and difficulty in miniaturization.

Electromagnetic tachometers, such as those based on Hall effect sensors[6], provide improved accuracy but may suffer from interference caused by magnetic fields in the environment. Moreover, these tachometers have limitations in their analog nature, which makes digital integration very difficult. In applications requiring high precision and digital communication, these systems may not be sufficient.

2.2 Optical Sensors for Rotational Measurement

Optical sensors as shown in Figure 1, provide a non-contact method for measuring rotational speed. Optical tachometers typically

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consist of an infrared (IR) emitter and a photodiode detector. A reflective marker placed on the rotating object reflects the IR light back to the sensor, generating pulses corresponding to the rotational speed. The absence of physical contact minimizes wear and increases reliability.[1.2,7].

Recent advancements in microcontrollers and optical sensing technologies have led to the development of digital tachometers that can provide real-time, accurate, and interference-free measurements. Optical sensors are particularly useful in environments with high-speed rotations and where contact with the rotating body is impractical.

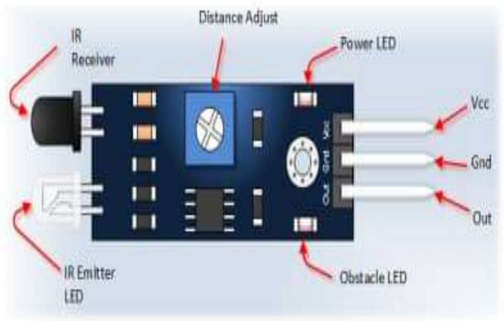

Figure 1. Optical Sensor

2.3 Microcontrollers in Measurement Systems

Microcontrollers are widely used in embedded systems for real-time data acquisition and processing. They are cost-effective, energy-efficient, and offer flexibility in terms of interfacing with sensors and displays.[3]. Microcontroller-based tachometers allow for digital measurement, storage, and processing of data, which is essential for modern industrial applications.

III. MATERIALS AND METHODOLOGY

The design was approached with extensive literature reviews on existing designs while hard ware design looked into selection and interfacing microprocessor and sensor, breadboard circuit design as shown in Figure 2 and 3 and software development with testing and evaluation of result. The designed digital tachometer consists of the following key components:

1. Optical Sensor: A reflective optical sensor detects the rotational speed by generating pulses as a marked surface on the rotating object passes by the sensor.
2. Microcontroller: A microcontroller, such as an Arduino or PIC microcontroller, is used to count the pulses generated by the optical sensor and calculate the RPM.
3. Display Unit: The calculated RPM is displayed on a digital display, such as an LCD or LED module.
4. Power Supply: A regulated power supply is used to power the system components.

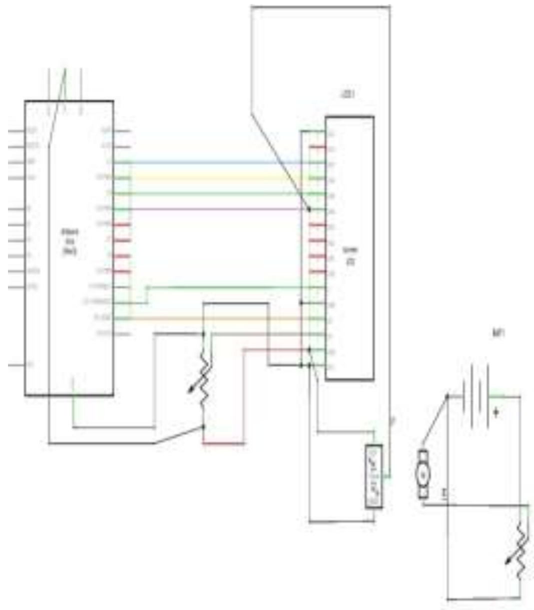

Figure 2. Circuit wiring

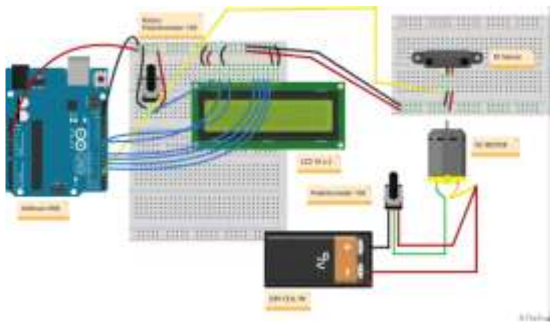

Figure 3. Layout of component and wiring

The optical sensor comprises an infrared (IR) emitter and an IR receiver (photodiode). The emitter sends out an IR beam, which is reflected back by a reflective strip placed on the rotating object. As the object rotates, the sensor detects the presence or absence of the reflected IR beam. Each reflection is counted as a pulse, and the number of pulses per second can be used to calculate the rotational speed.[3,8].

The time between two consecutive pulses is inversely proportional to the speed of rotation. If N pulses are detected over a time period T, the RPM can be calculated using the formula in Equation 1:

$$RPM = \frac{60N}{T} \quad (1)$$

where N is the number of pulses counted within the time interval T and Revolution per minutes RPM

The microcontroller processes the pulse signals from the optical sensor to compute the RPM. The microcontroller's timer interrupt feature is used to count the number of pulses per unit time.[8,9]. Based on the number of pulses, the microcontroller calculates the RPM and updates the display. A flowchart of the program running on the microcontroller is shown in the Figure 4

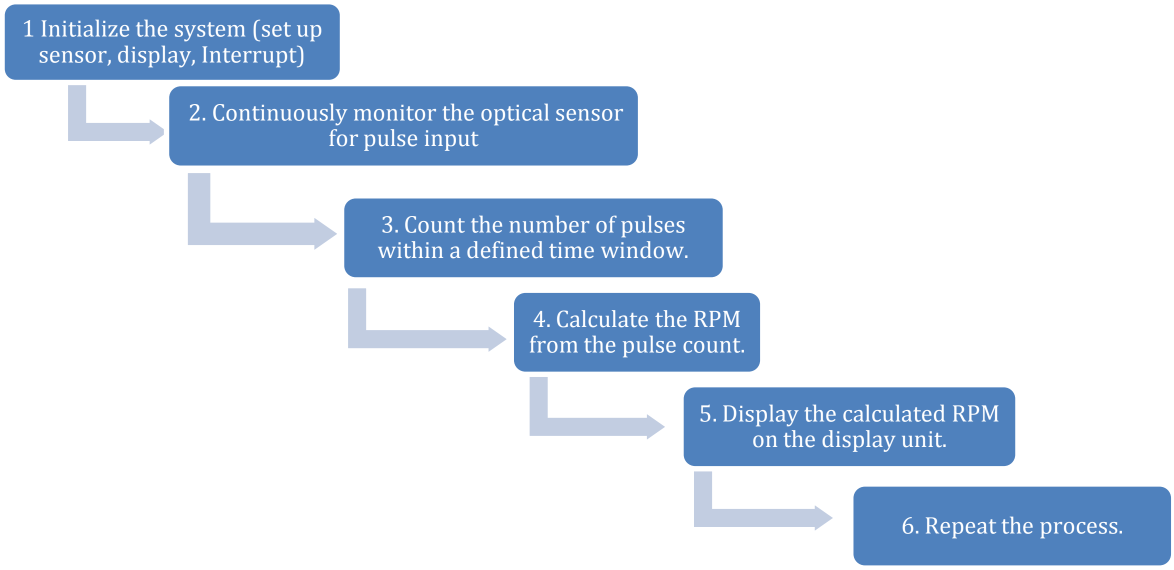

Figure 4. Flowchart of program running on Microcontroller

The microcontroller also manages the filtering of sensor noise and ensures that false signals caused by environmental factors, such as ambient light, do not affect the accuracy of RPM measurement.

The hardware components used in the development of the digital tachometer are listed as follows:

Microcontroller: Arduino Uno was used for this implementation, but any microcontroller with sufficient processing capability can be used.

Optical Sensor: An infrared emitter-receiver pair (such as the TCRT1000 or 5000) was used to detect the rotating object's reflective marker.

Display: A 16 x 2 LCD was interfaced with the microcontroller to display the RPM.

Power Supply: A 9V DC power supply was used to power the system.

The circuit design was carried out by connecting the optical sensor to one of the input pins of the microcontroller, where pulse signals are detected. The display is connected via the I2C bus for efficient communication with the microcontroller. The power supply is regulated to ensure consistent operation. A key part of the design is the software running on the microcontroller. The Arduino Integrated Development Environment (IDE) was used to write the program, which configures the sensor input, counts the pulses, and calculates the RPM.

IV. RESULTS AND DISCUSSION

The digital tachometer shown in Figure 5 was tested on various rotating machines, including a small DC motor and a fan. Reflective markers were attached to the rotating parts, and the optical sensor was positioned to detect the reflections. The system accurately measured the rotational speed in real-time, with the RPM displayed on the LCD.

The optical sensor-based system demonstrated high accuracy (± 0.1), with deviations of less than 1% and resolution (1rpm) when compared to commercial digital tachometers. The non-contact nature of the system ensured consistent performance, improved reliability and robustness when compared to the traditional analog tachometer, especially in high-speed applications where traditional tachometers might face wear and tear.

Figure 5.Developed digital tachometer.

V. CONCLUSION

The developed digital tachometer using a microcontroller and an optical sensor proved successful in providing an accurate, low-cost, and efficient solution for measuring rotational speed. The system's non-contact nature, ease of use, and ability to provide real-time digital data make it ideal for industrial applications, automotive systems, and embedded devices. However, it is recommended to improve the system’s sensitivity, expanding its application to multi-axis rotational measurements, and integrating wireless communication capabilities for remote monitoring.

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