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# DESIGN, CONSTRUCTION AND PERFORMANCE EVALUATION DETAILS OF A LOW COST CONTACTLESS-DIGITAL TACHOMETER

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## ABSTRACT

A Tachometer has been defined as a device used to determine the speed of rotation, typically of a shaft or rotating disc, usually measured in revolutions per minute (RPM). The constructed digital tachometer does this by taking advantage of the properties of the Infrared (IR) sensor to detect the body been measured. It also employs some mathematical computations to convert the IR detections to Revolutions per Minutes (RPM) by extrapolating the data. The entire device was built around the ATmega328-p Arduino Micro-Controller Unit (MCU) which uses the embedded C++ programming language. After Performance testing and evaluation of the device against a commercial tachometer a percentage error of 4.165% was observed, which is well within an acceptable range. The device promises several opportunities especially in automation, instrumentation and control as it can readily be put to use in the performance and evaluation of the agricultural processing machines and tractors alike in the center.

**KEYWORDS**: Tachometer, RPM, Micro-Controller, IR- sensor.

## 1. INTRODUCTION

Throughout the advancement of science, technology and engineering, there has been an ever pressing need to measure some of the parameters of the accompanying machines. In mechanical machines with rotations part, there is a need to know how fast these parts are rotating, either to performance, evaluation purpose, or for control/ regulate the measured system.

The Tachometer is a device employed to take the measurement of any rotating body/ component and report same in Revolutions per Minute (RPM). Several Tachometer especially those found in vehicles are similar in operation and design which the speedometer. The two devices differ greatly in their functions; the speedometer measures the continuous speed of the entire vehicle in mile/hour or km/hr while the tachometer measure the speed of the engine's instantaneous speed.

Some other parameters have to be considered which design/acquiring a new tachometer these include accuracy, range, precision, display type. The desired tachometer is therefore a contact-less digital tachometer, which a precise numerical output instead of an analogue display type.

Dietrich Uhlhorn, an engineer of German origin, in 1817 is widely believed to be the brain behind the development of the first analog tachometer and used it to determine the speed of machines (Fears 2017). The mono stable vibrator is the principle upon which the early tachometers operated, it also has a quasi-stable state and a stable state (Ismail, 2005). When the ignition system gets a pulse of current, it causes the stable state to change to a quasi-stable state. The reading is higher when the gauge setup receives a clean pulse of fixed interval. Voltage pulse is now used in tachometers developed nowadays rather than the current pulses, tachometers still use the mono stable multi vibrator technology. Value engineering was employed in the modern design of tachometers.

Padmanabhan, 2017 developed a tachometer using an AT89C2051 MUC, a Phototransistor and an arrangement of other components. It uses AT89C2051's internal timer for measuring the period of one cycle of the rotation in units of 100 microseconds. Thus, if the speed is 1500 RPM, it is 25 RPS, and the time taken for one cycle is 40ms. Similarly, Salice *et al*, 2014 and Omijeh and Ehihamenle, 2017 developed contactless tachometers using different MCUs and observed significant performance difference in newer version over existing models

**1.1 Types of digital tachometers**

The method used to measure the output and the acquisition of data forms the basis for grouping digital tachometers. Time and frequency tachometers are the tachometer types based on the measurement method while non-contact and contact digital tachometers are the types which are based on the mode of obtaining data.

### 1.1.1 Time measurement digital tachometer

This type of tachometer determines the speed based on the duration of pulses it receives from the moving object. This type of tachometer measures low speeds to a higher of accuracy and does not depend on the rate of the measurement.

**1.1.2 Frequency measurement digital tachometer** This type of tachometer determines the rate of the movement via the pulse frequency and is usually made with a Light emitting diode (LED) and it determines high speed to a high degree of accuracy. The rotation of the shaft is affected by tachometer revolution. Frequency based digital tachometers are very cheap but efficient which a frequency range of 1Hz to 12,000 Hz.

### 1.1.3 Non- Contact type digital tachometer

This type of tachometer does not need to come in touch with the moving shaft which is usually connected to an optical disk or a laser. Tachometers of this type tend to be very lucid from afar, condensed, precise and long-lasting.

### 1.1.4 Contact type digital tachometer

Tachometers of this nature are usually affixed to the electric motor and might also need to be connected to a sensor that has a magnet for determining its RPM.

## 2. Design and Methodology

The digital tachometer can be designed by various methods but this has been designed in such a way that the Arduino Nano V3 acts as the microcontroller, the LM 358 IR- sensor module is the detection device and proximity sensor while the HD44780 LCD is used for alphanumeric output. This particular tachometer is built around the Arduino MCU and the IR sensor. A number of works has been carried out on the micro-controller based digital tachometer. This configuration was chosen because it relies mainly on the micro-controller which can in turn be easily modified, optimized and expanded to accommodate more improvements.

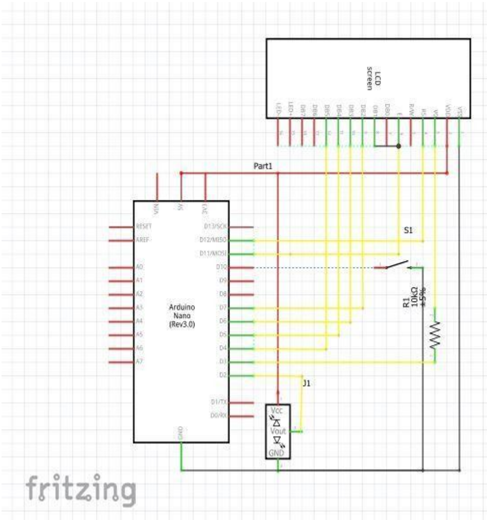


**Figure 1: Fritzing diagram of the circuitry.**

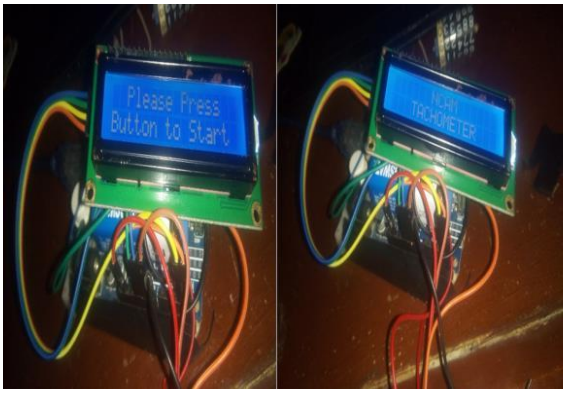


**Figure 2: Actual diagram of the NCAM tachometer.**

**Principle of Operation**

The system works mainly on infrared transmission principle. The device is essentially comprised of three (3) units. The input unit (the IR sensor) which is responsible for data acquisition from the rotations. This obtained value will be displayed on the LCD screen.

### 3.2.1 Mathematical Reference

The electrical pulses for the sensor are converted to RPM using the empirically deduced relation.

$$RPM = \left(\frac{Counter}{50}\right) \times 60$$

Immediate environment. The Processing Unit (The MCU, Arduino nano) which is charged with the responsibility of processing the data from the input device and churning the data using a preset of programs to produce a user friendly and accurate information. The Output unit (The LCD) this is simply to provide a human interface for information visualization.

The IR sensor is placed in front of rotating object of interest at 90 degrees at a maximum distance of 10 cm for accurate data capture and a white reflective tape placed on the rotating body, for reference because once the wheel starts rotating this light ray will be interrupted. The light ray will be reflected back on the reflective tape and will be absorbed by the phototransistor. (PRATEEK et al, 2017). This interruption of light ray is continuous in each and every rotation. This interruption of light ray is continuous in each and every rotation. This results in pulse of light ray that is fed to the microcontroller. The microcontroller counts the number of pulses and that in turn is the number of

Where:

Counter is the number of electrical pulses from the sensor 5 is the delay of 5 seconds for data acquisition from the sensor 60 is the conversion of the Revolutions Per Seconds (RPS) to Revolutions Per Minute (RPM).

## 4 Device Testing And Performance Evaluation

The newly designed tachometer was subjected to a series of performance tests in comparison with a commercially available tachometer to find out the electrical and electronics characteristics of the new tachometer and its performance, to determine the optimal performance range of the new device and to determine the degree of accuracy of the new device. The materials utilized for the evaluation of the newly constructed tachometer include: -

**1. The new tachometer**

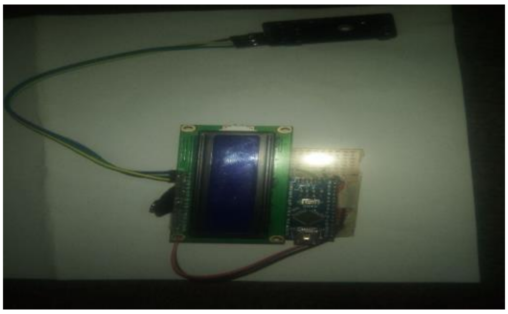

**Figure 3: Newly constructed Tachometer.**

2. **Commercial Tachometer (MAETECH DT- 2234A)**

**Figure 4: Commercial Tachometer (MAETECH DT-2234A).**

3. **A 24 V DC motor**

**Fig. 5: The two tachometers with the 24VDC motor.**

4. An Oscilloscope
5. A Lab-bench Power supply Unit

**4.2 METHODOLOGY**

The Test was carried out by connecting the 24V DC motor to the Lab-bench power supply and the voltage to the motor was gradually increased by a step of 0.5 V increment. Readings were taken by the two tachometers and recorded. The two (2) tachometers were utilized to measure the speed which was increased.

**4.3 Observations**

**4.3.1During Test**

1. The commercial tachometer produced inconsistent results as it fluctuated wildly over a range of values at a given motor speed, while the new tachometer produced consistent results and even when repeated severally at a given motor speed.

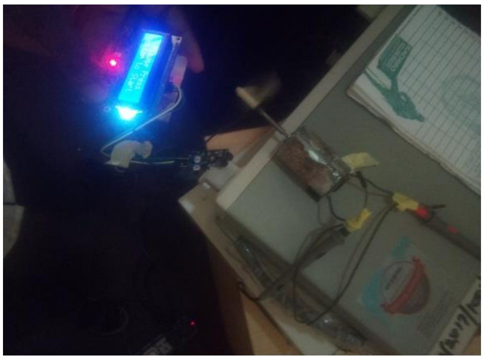

**Figure 6: Picture taken during data acquisition using the new tachometer**

## RESULTS

**Table 1: Test and evaluation of constructed NCAM tachometer against already existing commercial tachometer.**

| Voltage (V) | RPM of Commer cial Tachom eter | RPM of NCAM Tachometer |
|---|---|---|
| 2 | 456 | 468 |
| 2.2 | 497 | 480 |
| 2.4 | 585 | 588 |
| 2.5 | 634 | 624 |
| 3 | 792 | 792 |
| 3.5 | 984 | 972 |
| 4 | 1187 | 1176 |
| 4.5 | 1342 | 1356 |
| 5 | 1548 | 1488 |
| 5.5 | 1694 | 1608 |
| 6 | 1925 | 1584 |

The figures below showed the responses of the NCAM tachometer and commercial tachometer used to taking speed using oscilloscope. When the readings were superimposed on one another, it gave almost a perfect reading however the percentage error calculation was used to observe the marginal error of the newly constructed tachometer. The new tachometer reached it maximum accurate measurement speed at 1500 RPM above which the results became inconsistent with the expected result. Hence the test was terminated at this stage. It was observed that the marginal error increases as the speed goes beyond 1,500 RPM.

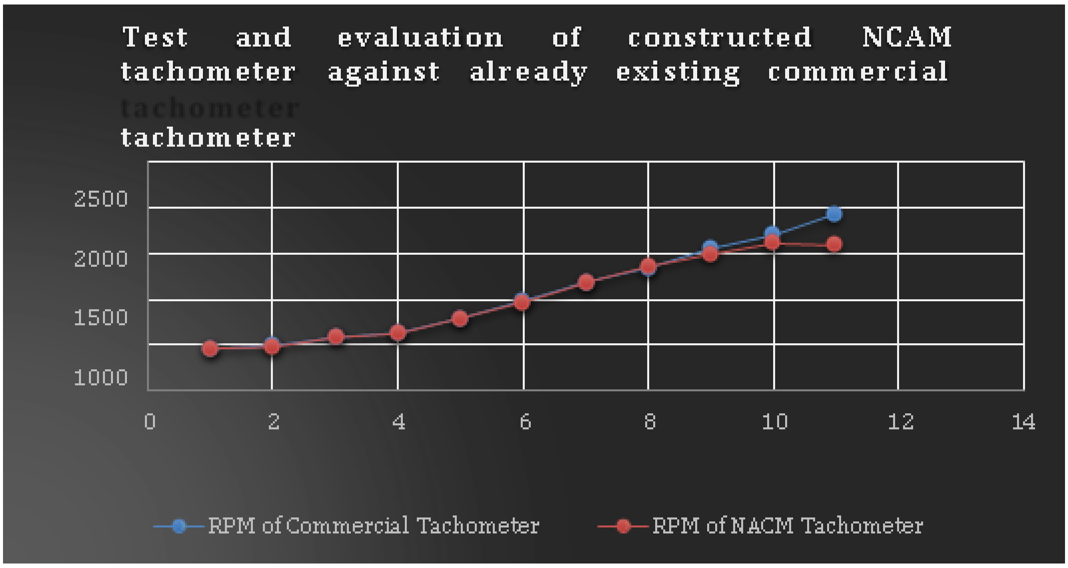


**Figure 7: RPM of new tachometer vs RPM of commercial tachometer.**

## Result Interpretation

The two results closely corresponded until around 1500 RPM where the NCAM tachometer got to its maximum range. Using the formula for % error calculation (Anne, 2019).

$$\%Error = \frac{\sum_{NcamTachometer} - \sum_{commercialTachometer}}{\sum_{CommercialTachometer}} \times 100$$

Where

Σ Ncam Tachometer = 11,136

Σ Commercial Tachometer = 11,620

## CONCLUSION AND RECOMMENDATION

### 4.4 Conclusion

The circuit is an innovative device that is active in measuring the speed of a rotating object. This device is nothing but a simple electronic digital transducer. Normally, it is used for measuring the speed of a rotating shaft. The number of revolutions per minute (rpm) is valuable information for understanding any rotational system, it is not prone to wear due to contact from the measured disc or shaft.

After the careful design, fabrication, testing and evaluation of the tachometer, it can be concluded that the tachometer is a strong and viable contender for the currently available tachometer and has proven to be of high precision. It is therefore safe to consider it as an alternative to the commercial tachometer, given the obtained degree of error which is less than

5%.

**4.5 LIMITATIONS**

From the various tests and performance evaluations the following limitations were observed;

1. That maximum limit of the device was around 1500 RPM, this could however be easily improved through minor improvement in the hardware configuration to extend to well above 5000 RPM
2. The device has difficulty taking measurement against any other background other than a dark/black color
3. The limitation of the project is that it incorporated an uncased component which are susceptible to noise. February 17, 2017. https://www.caigauge.com/blog/the- history-of-the-tachometer (accessed November 22, 2019).

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