

Design of a Low-Cost Contact-Less Digital Tachometer with Added Wireless Feature

Nitin Singh, Raghuvir S. Tomar

Abstract:- This paper proposes a hardware design of an “Digital Contact-less Tachometer” based on IR sensor for measuring the Revolutions Per Minute (RPM) of a rotating object. Conventional tachometers require direct contact with the rotating object which may affect its RPM and thus affecting the accuracy of the tachometer. This Tachometer design allows the measurement of the RPM without any direct contact with the rotating object. For more stable and accurate results a new algorithm is also proposed in this paper which allows the results to be displayed within a second. The design is also capable of sending RF signals which allows one to send the measured values to a distant place for its further processing. The RF feature also facilitates the data logging for monitoring and controlling the varying values of the RPM. The circuit design is simple, cheap and provide reliable results. Its stability and reliability has been verified through experiments.

Keywords – IR sensors; Opto-coupler; RPM; Tachometer; Rotating object.

I. INTRODUCTION

Tachometer is a device which is used to measure the rotational speed of a shaft or a disk in a motor or other machine. The word Tachometer came from Greek $\tau\alpha\chi\omicron\varsigma$, tachos, "speed", and metron, "measure". Tachometers are very useful in monitoring and controlling the Motors in industrial automation, such as in manufacturing plants of industries like chemical, pharmaceutical and textile or it may be a flat-belt and flow-control application. The conventional Tachometers require contact between the device and the rotating body, there are many situations where the direct contact between the tachometer and the device under investigation is not possible. To deal with such situations we need a tachometer which doesn't require direct contact with the rotating body, such tachometers are known as Contact-less Tachometer. In some cases the contact-less tachometer solely does not serve the purpose, as in the case of applications where continuous monitoring of the RPM is required and the test object is placed far away from the monitoring station, in such cases we need a Tachometer which can send the measured values to a remote processing unit. Considering such situations, the capability of sending RF signals is also added to this design by using RF ICs whose typical range of transmission is about 30 meters, which can be easily increased by using more sophisticated ICs.

This paper proposes the design of a low cost contact-less tachometer with added wireless feature to transmit the results at some distant place for further processing. This design also incorporates a new algorithm for calculating the RPM with higher precision.

II. THEORY

Digital Tachometers are used for precise measurement and monitoring of all time related quantities, which can be converted into a proportional frequency using appropriate sensor. For non-contact tachometers optical sensors are most suitable especially the reflective optical sensors. The design proposed in this paper makes use of the reflective IR sensor “TCND 5000”, which is used to convert the angular velocity of the rotating body into corresponding frequency. Once the Frequency corresponding to angular velocity is known it can be used to calculate the RPM using any one of the following methods [1].

- 1) Direct pulse counting,
- 2) Single pulse time measurement,
- 3) Constant elapsed time (CET),
- 4) Pulse time measurement using a variable number of counted pulses.

Results have shown that the first two methods are suitable only for low RPM whereas the third method is good for medium and high RPM. In this paper third method is used for calculating the RPM. An improvement to the CET method is adopted by counting the number of pulses for only 1/4th of a second and then averaging the three readings. The averaged value is then multiplied by 3 to make it RPS (Revolution per second) and then multiplying it by 60 to convert it into RPM. The averaging of the readings provide more accurate, stable and less fluctuating results. The whole calculation is done by the remote processing unit which comprises of a microcontroller “AT89C2051”. The results are displayed using the display unit which comprises of driver circuit and 4 digit 7-segment display. By using RF ICs the sensor unit and processing unit can be placed far from each other. In many applications where the object, whose RPM is to be measured is placed where the human entry is not possible and also, in applications where the RPM of different spinning objects or Motors need to be monitored and displayed at a common place requires the transmission of tachometer's signal to a distant place.

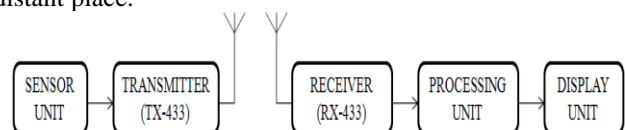


Figure 1. Block Diagram of the Design

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The addition of RF ICs to the tachometer design will fulfill the requirements of such applications. The design proposed in this paper uses TX-433 and RX-433, which uses ASK modulation technique, for transmission and reception of the Tachometer's signal. The block diagram of the design is shown in Figure 1.

III. DESIGN AND ANALYSIS

The whole design is divided into two parts a transmitter section and a receiver section. The transmitter section comprises of sensor, Operational amplifier and ASK transmitter and the receiver section comprises of ASK receiver, Processing unit and Display unit. The circuit diagram of the Transmitter section and the Receiver section is shown in Figure 2(a) and 2(b), respectively. The sensor unit consists of an IR sensor "TCND 5000" manufactured by 'Vishay Semiconductors' and a NPN transistor BC 548 (Q1). The TCND 5000 is a reflective sensor that includes an infrared emitter and PIN photodiode in a surface mount package which blocks visible light and there is complete optical isolation between the emitter and the photodiode [2]. To convert angular velocity into the corresponding frequency a small reflective strip is placed on the rotating object which can then be detected by the sensor whenever it passes from its front. Whenever the reflective strip passes from the front of the sensor, some part of IR light gets reflected from it which increases the voltage across the Photo-diode. The output produced by the sensor is generally very low and needs to be amplified, which is done by the transistor Q1 and Q2. The emitter of the TCND 5000 has an absolute maximum forward current rating of 100mA, so for the reliable use of the device it is operated at 85mA using a current limiting resistor R1.

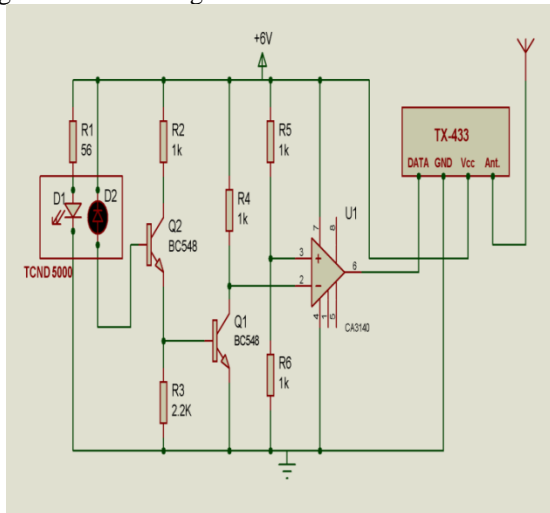


Figure 2 (a). Transmitter Section

The emitter is connected in current driven mode with forward biasing. The detector of the TCND 5000 is connected in reverse bias mode, it can withstand a maximum reverse bias voltage of 60V. Whenever some reflected light strikes on detector its output current increases appreciably but it is not large enough to drive the transistor Q1 into saturation region. Therefore a transistor Q2 is used which provides sufficient amplification to drive Q1 into saturation region. A voltage divider resistor network using R5 and R6 is used to set the reference voltage of the comparator at 3V [3], in this design CA3140 IC is used as a comparator. For wireless transmission of the comparator's output, pin no.6 of the Op-amp is connected to the 'DATA'

pin of the ASK transmitter IC "TX-433", which transmits the signal at 433 MHz. For the reception of the transmitted ASK modulated signal RX-433 RF IC is used. Both TX-433 and RX-433 supports a data rate of upto 10Kbps, which is sufficient for this design. The demodulated output of the RX-433 is then fed to the processing unit, which consists of a microcontroller "AT89C2051" manufactured by ATMEL CORPORATION. The "AT89C2051" comes with an inbuilt analog comparator [4] which reduces the hardware complexity. The data pin of RX-433 is connected to the pin no.13 and the reference voltage, which is set at 2 Volts using 4.7k preset, is fed to the pin no.12 of the microcontroller. The pin no.12 and pin no.13 of "AT89C2051" are non-inverting and inverting terminals of the inbuilt comparator [5], respectively.

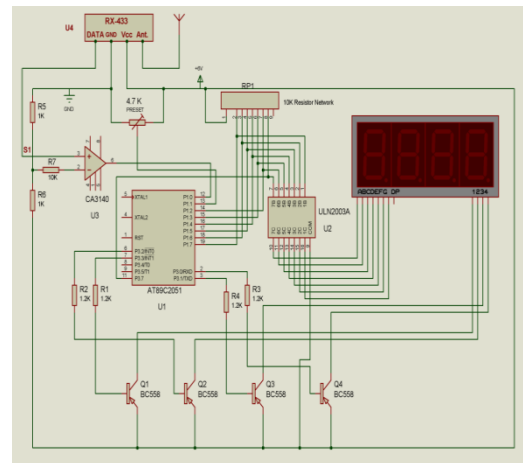


Figure 2(b). Receiver Section

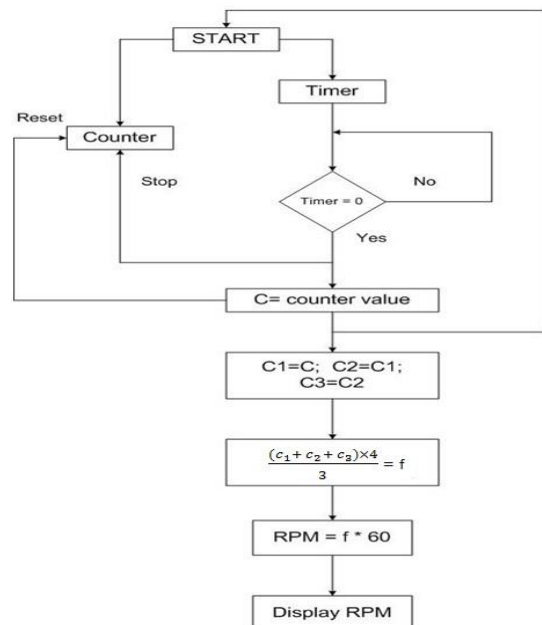


Figure3. Frequency based algorithm.

The input to the microcontroller is basically a train of pulses where each pulse corresponds to one revolution, thus the total number of pulses in one second corresponds to the Revolutions Per Second (RPS) of the spinning object.

The inbuilt counter and timer of the AT89C2051 are used to calculate number of pulses in 1/4th of a second, such three values are first averaged and then converted into RPM. The flow-chart of the algorithm is shown in Figure 3. If the average value is 'R' i.e there are R number of pulses in 1/4th of a second then the RPS will be '4xR' and the RPM will be '4xRx60'. The results obtained from the Processing unit are then fed to the display unit which consists of a Darlington Transistor array IC ULN2003 and common cathode 4 digit 7-segment display. The port P1 is connected to the pin no.1 to 8 of the 'ULN2003' which derives the 7-segments of the display. All four 7-segments are illuminated one by one with very short time delay, which cannot be perceived by human eyes, so that all four 7-segments appear to be illuminated simultaneously. Port P3 pins: P3.3, P3.2, P3.1 and P3.0 are used for selecting one of the four 7-segments at a time. P3.3 and P3.0 are connected to that segment which displays the Most Significant Digit (MSD) and the Least Significant Digit (LSD), respectively.

IV.CONCLUSION

The experiments have shown that this design is stable and feasible. The experiments have also proved that the results obtained using the proposed algorithm are better than the normally used algorithm which counts the number of pulses for 1 second. For RPM values greater than 300 this algorithm works very well and the results are more accurate and stable. It's major feature is that it does not require direct contact with the rotating object for measuring the RPM. This design can be extended by adding data logging feature to it, data logging is widely used in industries to keep the track of the varying RPM of the shaft of a Motor or any other rotating object. This Tachometer design's capability of sending RF signals increases its area of application and makes it more versatile than the conventional Tachometers. Also, for data logging the RPM values can be sent to a distant 'Monitoring unit', using on board RF ICs. Many such Tachometer units can also be connected to a central 'Processing Unit' which will ease the simultaneous monitoring of different Motors, Turbines, and other spinning objects. It's accuracy and capability of measuring high RPMs makes it an very good choice for different industrial applications. Beside, these advantages this design has few limitations, such as RPM values less than 300 cannot not be measured effectively using the proposed algorithm; this can be overcome by using different algorithm for different range of RPM values. For better results the 'sensor unit' needs to be place very near to the rotating shaft around 20 to 30 mm, this distance can be increased by using highly sensitive optical sensors. The capability of this design resides in the capability of the 'Processing Unit', for measuring RPM values greater than 1,25,000, microcontrollers such as AVR, with much faster processing speed can be used without changing the algorithm and other circuitry. It's portable, easy to use and cheap design makes it suitable for the domestic and household applications. This design has great development potential and has a stable and reliable performance in long run. The features of the design are light weight, small size, low cost, high sensitivity and timeliness.

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