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Design of Digital Tachometers Based on Different sensing Techniques

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Abstract— In industries, machinery and devices, the speed of rotating part or motors needs to be measured to monitor or to control the system especially in servomechanism. Tachometer is an instrument which is used to measure the rotation speed of a shaft or disk, as in a motor or other machine. It measures the rotational speed in the unit revolution per minute (RPM). This paper provides a detailed study on the design and development of contactless tachometer based on different techniques. First design of a simple, easy to implement magnetic type Reed relay based tachometer, Second design of Hall sensor based tachometer and finally IR based tachometer by using low cost linear digital integrated circuits (ICs). We have developed a model which counts the rotation using different sensor techniques and analyzed for the sensitivity for handling speeds with vast range of rpm. With the help of a microcontroller speed can be calculated and displayed.

Keywords—Servomechanism, tachometer, RPM, Reed relay, Hall sensor

I. INTRODUCTION

In this modern world all industries have motors whose speed has to be monitored properly. A rotating object may be a bike tyre, a car tyre or a ceiling fan, or any other motor. For monitoring and controlling applications the speed has to be determined precisely and one such speed measuring device is tachometer. The word tachometer is derived from two Greek words: "tachos" means "speed" and "metron" means "to measure". It works on the principle that when a motor is operated as a generator, it produces the emf if it is based on electromagnetic induction according to the velocity of the shaft. Its operating principle can be electromagnetic or optical-based. Tachometer is specified on the basis of power, accuracy, RPM range, measurements and display. Tachometers can be analog or digital indicating meters; but, this article focuses only on the digital tachometers based on both the electromagnetic as well as optical sensing principle [1].

Previously there exist mechanical tachometers, tachometer is in contact with the rotating shaft for measurement of RPM. But this kind of tachometers needs regular maintenance, complicated to use and also suffer from wear and tear. In this modern era of digitization and evolution of new sensor techniques contactless digital tachometer can be easily designed and used with monitoring system. This paper is about contact-less digital tachometer designed using three different sensing techniques. One is Reed Relay based and second is Hall Effect Sensor based, both of these techniques works on the principle of electromagnetic induction. And the last one is based on infrared methodology in which it works on the principle that the number of times the IR receiver transmitter circuit is cut and re-established in a second gives the number of rotations per second [2].

II. HARDWARE REQUIREMENTS

1. Reed Relay:
A reed relay is a type of relay that uses an electromagnet to act directly on reed-like contact of a reed switch contained within a glass envelope, typically bringing the reeds together to make contact when the electromagnet is energized. A reed switch is an electrical switch that does not require power to operate. The contacts are hermetically sealed within a glass tube with precious metal contact material. As a result, the switch is highly reliable because it is unaffected by moisture or other environmental factors. The operation of the reed relay is quite straightforward. It works by placing a magnetic field close to the reed switch contacts. This causes each of the reeds to become magnetically orientated such that the two ends of the reed attract each other and move together closing the contact. When the coil voltage is removed or under conditions where no magnetic field is applied, the blades separate by their own spring tension.

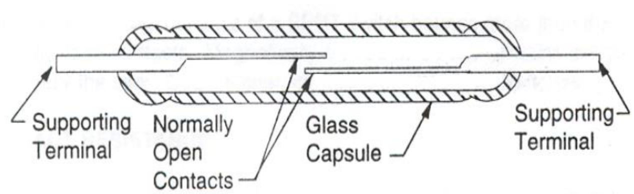

Figure.1. Reed Relay

2. Hall Effect Sensor:

Hall Effect sensor is a solid state device which detects magnetic field and respond according to the changes in field strength and convert magnetic or magnetically encoded information into electrical signals for processing by electronic circuits. The Hall element is the basic magnetic field sensor. It requires signal conditioning to make the output usable for most applications [3].

Hall Effect:

When a current-carrying semiconductor material is placed into a magnetic field, the magnetic flux lines exert a force on the semiconductor material which deflects the charge carriers, electrons and holes, to either side of the semiconductor slab. This movement of charge carriers is a result of the magnetic force they experience passing through the semiconductor material. As these electrons and holes move side wards a potential difference is produced between the two sides of the semiconductor material by the build-up of these charge carriers. Then the movement of electrons through the semiconductor material is affected by the presence of an external magnetic field which is at right angles to it. A voltage will be generated perpendicular to both the current and the field. This principle is known as the Hall Effect [4].

Figure 2 illustrates the basic principle of the Hall Effect. It shows a thin sheet of semiconducting material (Hall element) through which a current is passed. The output connections are perpendicular to the direction of current. When no magnetic field is present, current distribution is uniform and no potential difference is generated at the output. When a perpendicular magnetic field is present, a Lorentz force is exerted on the current. This force disturbs the current distribution, resulting in a potential difference (voltage) across the output. This voltage is the Hall voltage (VH). The interaction of the magnetic field and the current is shown in equation form as equation 1. The Hall voltage is proportional to the vector cross product of the current (I) and the magnetic field (B).

$$VH \quad \alpha \quad I \times B$$

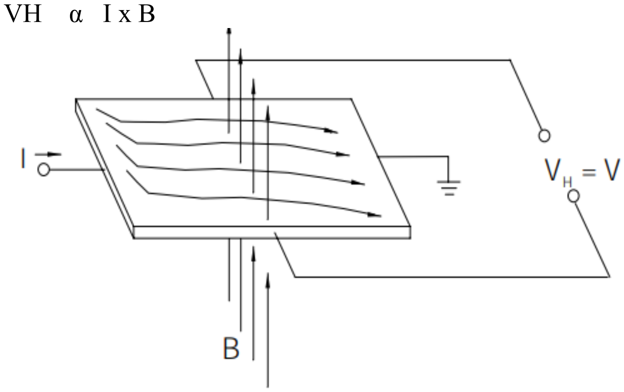

Figure.2. Hall Effect

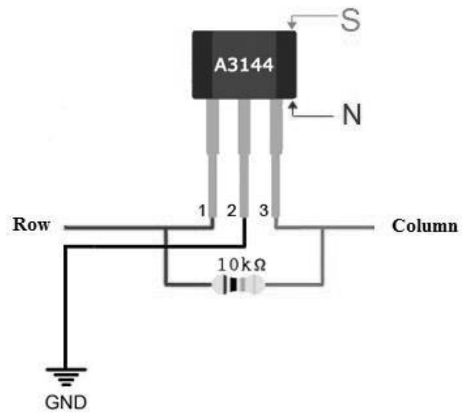

Figure.3. A3144 Hall Effect Sensor

3. IR sensor:

An IR sensor consist of infrared light emitting diode which is used as a source of light which falls on the strip made of radium of rotating object. Infrared light is invisible with wavelength of 0.7—2µm. The IR light is received by the reflection of light with the help of infrared light source circuit. The reflected light from a rotating body falls on the junction of the sensor module consist of photodiode to activate and deactivate it alternately [5]. If the obstacle is black colored the IR rays are absorbed and if it is light colored the IR rays are reflected and detected by photodiode.

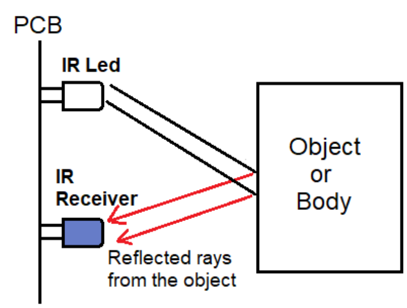

Figure.4. IR principle

Figure.5. IR sensor module

4. Opto-coupler 4N35:

Opto-coupler is an electronic component provides electrical isolation that is the two circuits are optically connected but electrical signals are transferred between two isolated circuits. From its pin configuration pin 1 and pin 2 are connection for LED (Light Emitting Diode), the LED emit infrared light to the photosensitive transistor that is between the pin number 4 and 5. The photo-transistor switches the output circuitry by its collector and emitter. The intensity of the LED directly controls the current in photo-transistor. Also, between the photo-transistor and the IR LED, the space is transparent and non-conductive material; it is electrically isolating two different circuits. The hollowed space between LED and photo-transistor can be made using Glass, air, or a transparent plastic, the electrical isolation is much higher, typically 10 kV or higher [6].

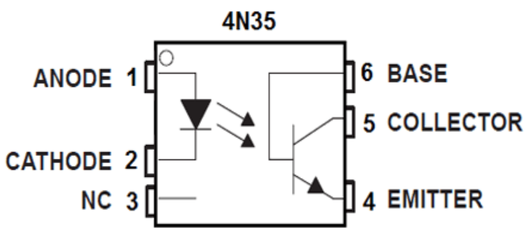

Figure.6. Opto-Coupler 4N35

5. Decade Counter CD4033:
CD4033 is the Johnson Decade counter with Decoder. The output decoder converts the Johnson code to a seven segment decoded output which can drive LED or 7 segment display in numerical values. In usual operation, the Reset pin and Clock enable pins are held at ground and the Ripple blanking input is connected to ground. Maximum clock frequency of CD 4033 is 5 MHz at 10 volts and 2.5MHz at 5 volts.

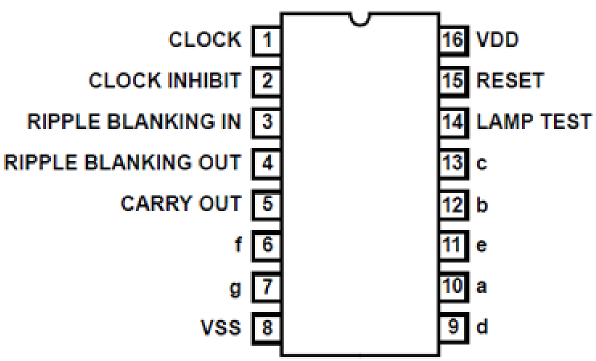

Figure.7. Decade counter CD4033

6. Microcontroller Arduino UNO:
Arduino UNO is open source embedded system which belongs to the family of ATMEL. It consists of a single board 8 bit microcontroller with 32kb of flash memory with a clock speed of 16 MHz [1]. The board are equipped with set of digital and analog input/output pins that may be interfaced to various module or external circuits. The boards feature serial communications interfaces including USB (universal serial bus) on some models which are also used for loading programs from PCs [7].

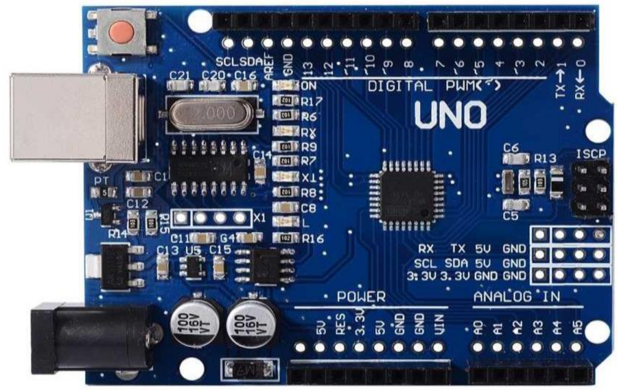

Figure.8. Arduino UNO

III. METHODOLOGY

Tachometer System Designs:
1. Reed Relay based Tachometer:
The tachometer works according to this principle;
A wheel or motor whose speed is to be determined consists of a rotor placed with a permanent magnet on it. An electromagnet and reed switch are placed close to the rotor on opposite sides. When a magnet on the rotor gets close to the reed switch, the reed switch gets magnetized and allows current to pass through and the current is passed to the Decade counter CD4033. The resulting count is then displayed and represents the speed of the rotating object. Counter is used to count the rotation, and displayed on the seven segment display.).

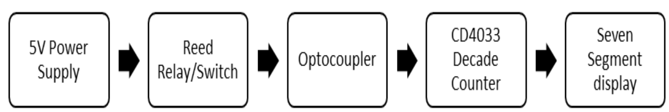

Figure.9. Block diagram for Reed based Tachometer

2. Hall Sensor based Magnetic type Tachometer:
By using latched Hall Effect sensor, rotational speed can be measured by counting the number of pulses per revolution. The tachometer shaft is made in contact with the motor shaft whose speed is to be measured and a number of magnets are mounted on tachometer shaft. Hall sensor is positioned stationary in such a way that it will closely face the rotating magnets. Since the output is in the form of pulses it becomes easy to manipulate the data. With the help of a microcontroller speed can be calculated and displayed [4].

A moving permanent magnet closely facing the sensor, which is sensitive to change in field strength, is the sensing element. The output range of a Hall Effect sensor is in the range of volts and can directly be given to the counter here we used CD4033 and displayed on the seven segment display.

As magnets moving field strength varies accordingly and the output of the sensor switches. When the magnet directly faces the hall element the output goes low and when the field strength is lowered the output become high. The sensor IC used is AH44E unipolar digital Hall Effect sensor by allegro. A digital Hall Effect sensor gives square wave in the range of volts and is of with less noise. Therefore signal conditioning became easy in this case. This is one of the advantages of Hall Effect sensor.

The number of output pulses for one revolution is the number of magnets mounted on the device shaft. Here it is taken one. Therefore per revolution we get single pulses. These pulses will trigger the counter and this logic helps to find the rpm. Number of pulses in one minute gives the revolution per minute.

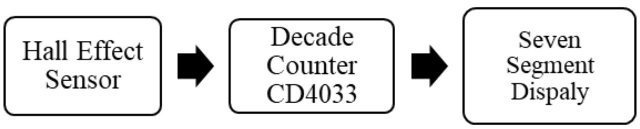

Figure.10. Block Diagram for Hall sensor based tachometer

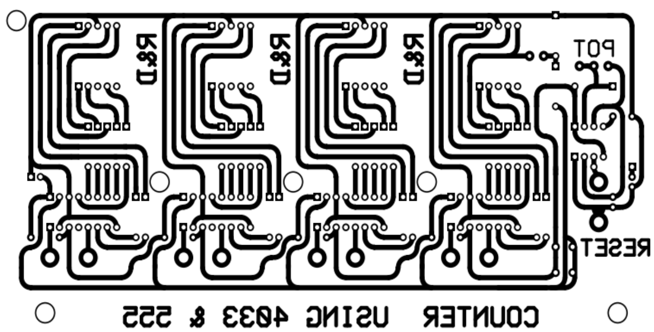

Figure.11. PCD Layout for above mentioned tachometers

3. IR based Tachometer

The IR device seemed to work better, up to about 1000 rpm. It is an electronic device that is used to sense infrared radiations either by generating or detecting infrared radiations. It contains Arduino UNO, IR sensor module and LCD. Arduino controls the whole the process like reading pulse that IR sensor module generate according to object detection, calculating RPM and sending RPM value to LCD.

As we all know that microcontroller plays a vital role in every part of electronics industry therefore we also have used Arduino UNO board which is based on the ATmega 328P microcontroller [8]. The IR sensor present consist of a LED and a photodiode [1]. A motor will rotate in front of the sensor, the light emitted from the LED will get reflected form the wheel and would fall on the photo diode thus the infrared sensor would give out a pulse as input to the Arduino UNO. The Arduino UNO is programmed to take 3 consecutive readings and take out their average. This average of three reading will be displayed to the 16x2 LCD screen.

IR sensor module output pin is directly connected to pin 18 (A4) of Arduino board. Vcc and GND are connected to Vcc and GND of Arduino. A 16x2 LCD for displaying the revolution speed is connected with Arduino in 4-bit mode [2]. The input to the microcontroller is 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 revolving object [9]. The inbuilt counter and timer of the Arduino are used to calculate number of pulses to be converted into RPM. Printed circuit board schematic designed using ExpressPCB software of IR based tachometer is shown in Figure 13.

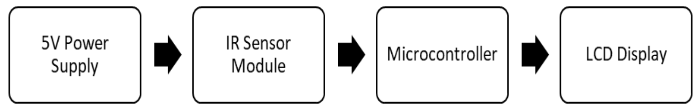

Figure.12. Block Diagram for IR sensor based Tachometer

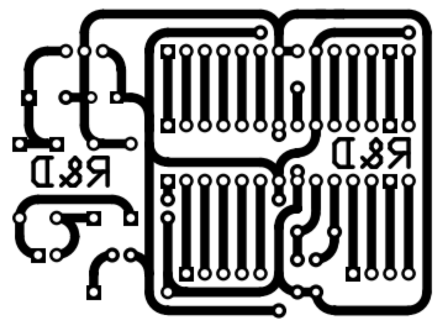

Figure.13. PCB design for IR sensor based tachometer

IV. RESULTS AND DISCUSSION

We have designed all the above three methods of the circuit to work with least error. The testing is done with each circuit and the designed tachometer is capable of determining the speed of the rotating body. The obtained result of the designed tachometer is shown in the seven segment or 16x2 LCD screen as shown below.

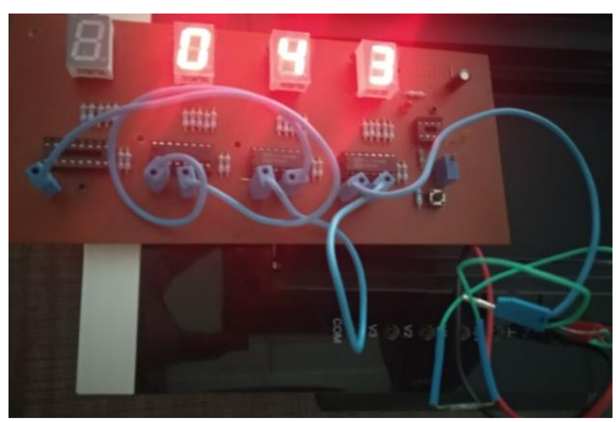

Figure.14. Tachometer design for Reed relay sensor

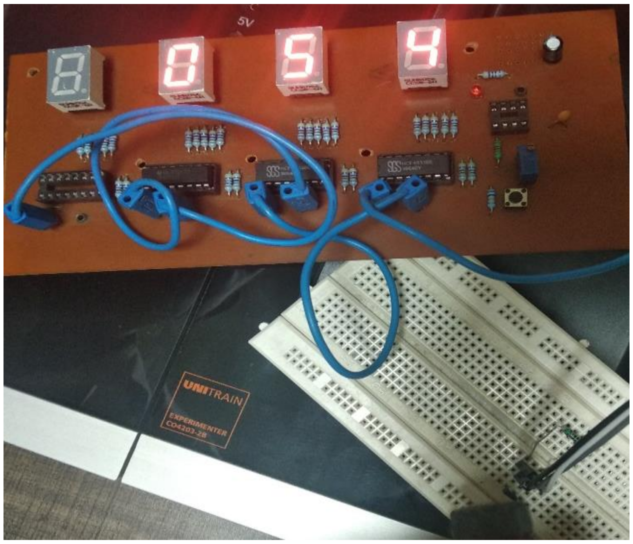

Figure.15. Tachometer design for Hall sensor

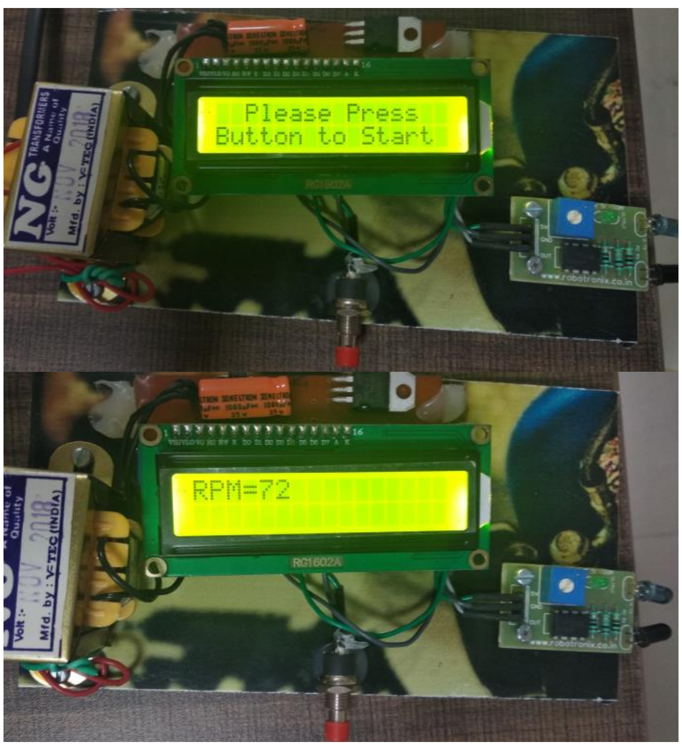

Figure.16. Tachometer design for IR sensor

Comparison of above mentioned techniques

Reed relay are small in size some are fitted into SIL, DIL packages etc or even smaller, fast switching speeds and Provide complete isolation between the switching current and the switched circuit. Unlike a reed switch, a Hall Effect device contains active circuitry, so it draws always a small amount of current. Hall sensors have high speed operation approximately 100 kHz possible whereas at high frequencies the inductive or capacitive sensor output begins to distort certainly it can measure zero speed also. The complexity compared to other tachometers is less here and no heavy signal conditioning employed.

Tachometer design using IR sensor with microcontroller has stable and reliable performance in long run and have high sensitivity. It is more efficient, quicker response and cheaper in cost. As it uses microcontroller so gives the measurement fast and accurate.

V. CONCLUSION AND FUTURE SCOPE

We find that the reed has very low on resistance typically as low as 50 milli-ohms, whereas the Hall Effect can be in the hundreds of ohms and the sensing distance for reed is about 40mm while Hall sensor can sense up to distance of only 20mm. The Hall Effect sensor can be considerably more expensive than the reed sensor. In contrast to it the third tachometer design using IR sensor has sensing distance range up to 2- 30 cm with only 20mA of driving current giving digital output with quick response time. Hall sensor and IR sensor both need the 5V of DC supply while Reed does not need external power for its operation. The proposed tachometers finds their applications in various fields, such as fast response over speed shut down, petrochemical production, pump or generator applications, low speed switching. Also they find possible applications to calculate speed of rotating wheels, discs and motor shafts and especially at places where direct contact with rotating object is not possible like in case of vehicles and industrial machines. The tachometer design can be further characterized for telemetric operation which will be capable to transmit information wirelessly at larger distance may be via Bluetooth or RF based communication. Speed monitoring is very essential in cutting tools in many industries to get accurate outputs so these tachometers can be used.

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Authors Profile

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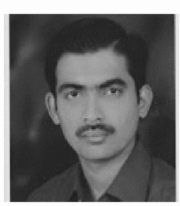

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