

Design and Development of Linear Velocity Measurement System using Texas Instruments Hall Effect Sensor DRV5023-Q1 and Microcontroller MSP430G2553

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Abstract

Objectives: Angular and linear velocity measurements play an important role in monitoring and controlling the speed of motors used in applications such as conveyors, turbines, robots, automobiles and other moving objects. In the present paper, an inexpensive and portable system for the measurement of rotations per minute (RPM), linear and angular velocities is developed using Texas Instruments Hall effect sensor: DRV5023-Q1 and microcontroller MSP430G2553. **Methods/Statistical Analysis:** A unipolar Hall sensor switch produces pulses when a tiny magnet is brought in its vicinity. These pulses are counted by using the microcontroller in a fixed time interval and number of pulses per second gives frequency or rotations per second (RPS). From frequency, RPM, angular and linear velocities are computed. **Findings:** The measured parameters are displayed on LCD. The experimental frequencies are compared with the frequencies measured using commercial frequency meter (PHILIPS PM6624D). The linearity in velocity measurement (RPM) is represented in the form of a graph. **Application/Improvement:** In the present work an inexpensive and robust system is designed and developed for the linear velocity measurement. Further, the system is portable and works on a single rechargeable 9V battery. Such systems can be used in complex environment also.

Keywords: Hall Effect Sensor, Linear Velocity, MSP430G2553, RPM, Tachometer

1. Introduction

Speed or velocity is a state variable defined as the time-rate of motion and the units of linear velocity is meter per second (m/s) and the units of angular velocity is radians per second or revolutions per minute (RPM). The instrument which measures the angular velocity or linear velocity is known as Tachometer. This word is derived from the Greek words 'tachos' and 'metron' meaning

speed and measure¹. The first mechanical Tachometer was designed based on measuring centrifugal force. In 1817, this principle was adapted for the measurement of speed of machines. They play a vital role in controlling or monitoring the speed of motors, conveyors, turbines, robots, vehicles and other moving objects. To diagnose circulatory problems like clogged arteries advanced tachometers like haematachometer is used to find the blood flow rate in arteries and veins².

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There are different types of tachometers. They are broadly classified based on readout: Analog³ and Digital⁴⁻⁶. Further, based on technique: contact and non-contact tachometers, and based on measurement method: time and frequency tachometers.

In literature different workers used different methods to measure angular velocity. In⁷ Proximity sensor is used to measure RPM. In⁸ an opto-coupler method is implemented. In⁹ Analog output Hall sensors were used as rotational speed sensors. In¹⁰ a compact electronic tachometer for unmanned aerial vehicle was developed using a remote hall sensor AH173 type.

In¹¹ a magnetic pickup sensor is employed to develop automatic speed measurement. In¹² a TSOP (Thin Small Outline Package) IR receiver is used to measure RPM. In¹³ a contactless rotor RPM Measurement was presented using Laser Mouse Sensors. In¹⁴ an optical incremental encoder and leap variable M/T method is adopted for speed measurement with high precision in a wide speed range. In¹⁵ Measurement of angular velocity based on video technology is presented. In¹⁶ Digital frequency meter using DMA Terminal Count Stop method is presented. In¹⁷ an incremental encoder's method is adopted for position and speed measurement. In¹⁸ a Hall sensor and Digital Signal Processor is used to evaluate the speed of the rotor of a servo system.

Majority of the techniques mentioned in the literature use complex circuits. Keeping this in view point, we have designed and developed linear velocity measurement system using Texas Instruments Hall Effect sensor switch DRV5023-Q1 and ultra low power microcontroller MSP430G2553. The advantages of the system are it is portable, inexpensive, operates with 9V rechargeable battery, non-contact type and using Hall sensor the frequency of measurement can be up to 30 kHz. The complexity

compared to other methods is less and no heavy signal conditioning employed.

2. Principle of Measurement

A circular disc of known radius r is attached to the shaft of a DC motor. The speed of DC motor can be controlled by a potentiometer. To the rim of the circular disc a small magnet is attached such that the south pole of the magnet faces the Hall effect sensor. When the magnet on the disc and Hall Effect sensor come in-line, sensor produces a pulse. The frequency of these pulses is measured; RPM and linear velocities are computed using the following formulae.

$$\begin{aligned} \text{Frequency, } f &= \text{number of pulses per second} \\ \text{RPM} &= f \times 60 \end{aligned} \quad (1)$$

$$\text{Linear velocity of the disc, } v = r \cdot \omega \text{ (m/s)} \quad (2)$$

$$\begin{aligned} \text{Here } \omega &= 2\pi f, \text{ Angular frequency (rad/s)} \\ R &= \text{Radius of the disc (m)} \end{aligned}$$

3. Proposed System

The entire system is described in two parts, namely, hardware and software descriptions.

3.1 Hardware Description

The block diagram of the proposed system is shown in Figure 1. It consists of the following blocks.

- DC motor with speed control using potentiometer

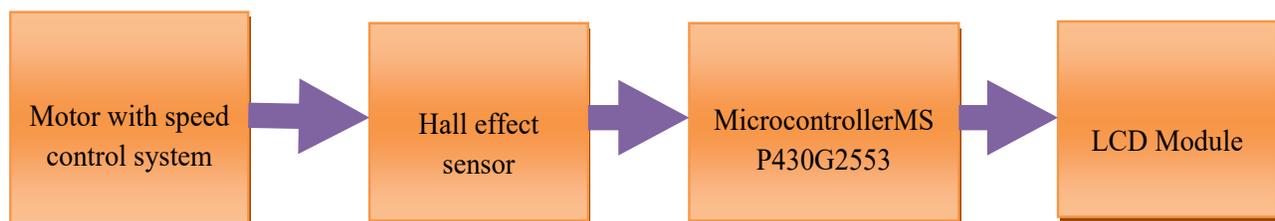


Figure 1. Block diagram of the developed system.

- Hall effect sensor-DRV5023-Q1¹⁹
- Microcontroller MSP430G2553²⁰
- LCD Module

3.1.1 Motor with Speed Control using Potentiometer

A circular disc of radius 0.035m is attached to the shaft of DC motor. The speed of rotation of the motor is controlled by a potentiometer and driver circuit using a transistor.

3.1.2 Hall Effect Sensor

Hall Effect sensor works on the principle of Hall Effect discovered in 1879 by Edwin Herbert Hall. According to Hall Effect when a current carrying conductor or semiconductor is placed in a transverse magnetic field, an emf or voltage is developed across the ends of the conductor which is perpendicular to both magnetic field and current directions. Figure 2 shows the principle of Hall Effect.

There are three types of Hall Effect sensors available on the market. The Hall Effect switch, the Hall Effect

latch and the ratiometric output Hall sensor. A Hall Effect switch will turn on in the presence of South Pole of a magnet on its face or North Pole of a magnet on the opposite side. It will turn off when the magnet is removed. A Hall Effect latch will stay on even when the magnet is removed. It will turn off if the North Pole is near to the face or the power is turned off. A ratiometric Hall Effect sensor output is an analog voltage proportional to the magnetic field intensity. When no magnetic field is applied, the output is one-half the supply voltage. The sensor's output voltage increases as the South Pole of the magnet approaches sensor's face and decrease with the approach of North Pole of the magnet.

The sensor used in the present work is Texas Instruments' DRV5023-Q1, is a unipolar Hall Effect switch. The features of the sensor are:

- Operates from 2.7V to 38V supply voltage with reverse voltage protection
- Operates with magnetic fields of bandwidth up to 30kHz

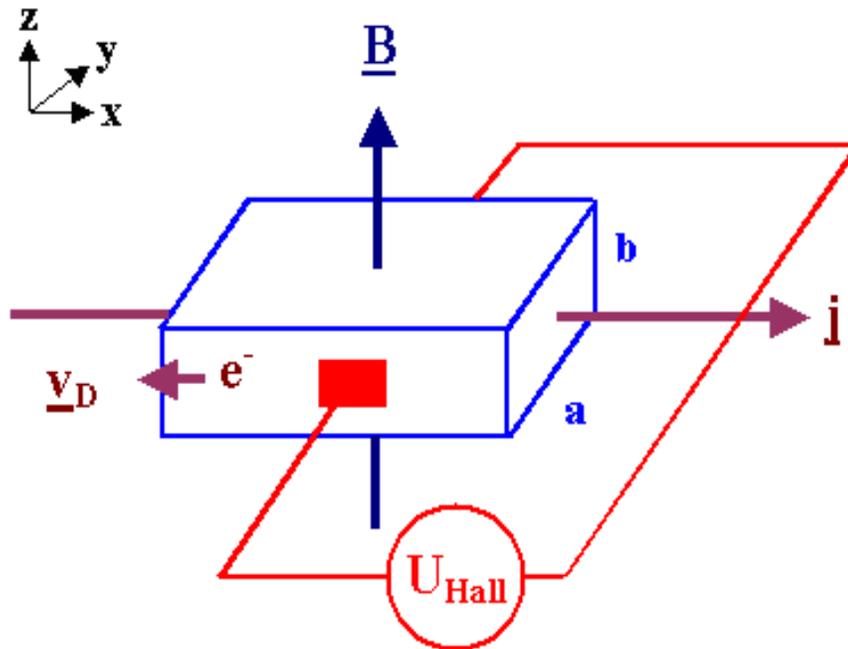


Figure 2. Principle of Hall Effect.

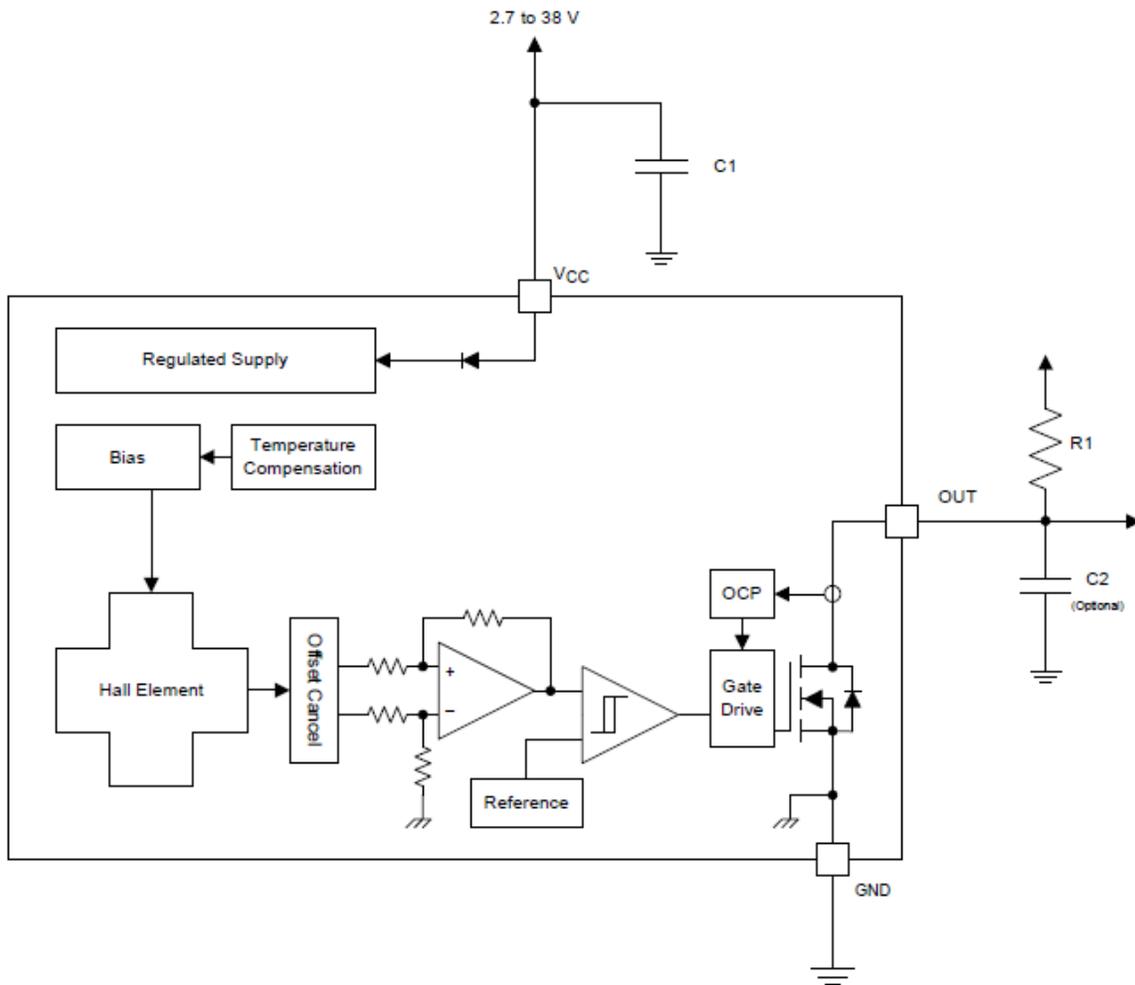


Figure 3. Functional block diagram of DRV5023-Q1 Hall sensor.

- On-chip Hall Sensor
- On (output is pulled low) with magnetic South pole and Off (output is released) without magnetic field
- Ideal sensor for docking detection, door open and close detection, proximity sensing, valve positioning and pulse counting.

The functional block diagram of the sensor is shown in Figure 3 and application circuit is shown in Figure 4.

3.1.3 Microcontroller MSP430G2553

The Texas Instruments' MSP430G2553 is an Ultra-Low-Power Mixed Signal Processor with Von Neumann architecture. It has a powerful 16-bit RISC Processor.

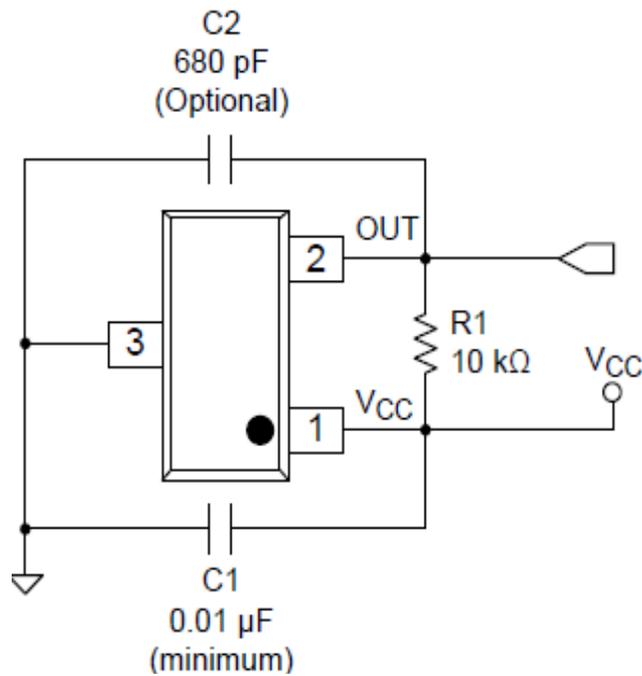


Figure 4. Application circuit of DRV5023-Q1 Hall sensor.

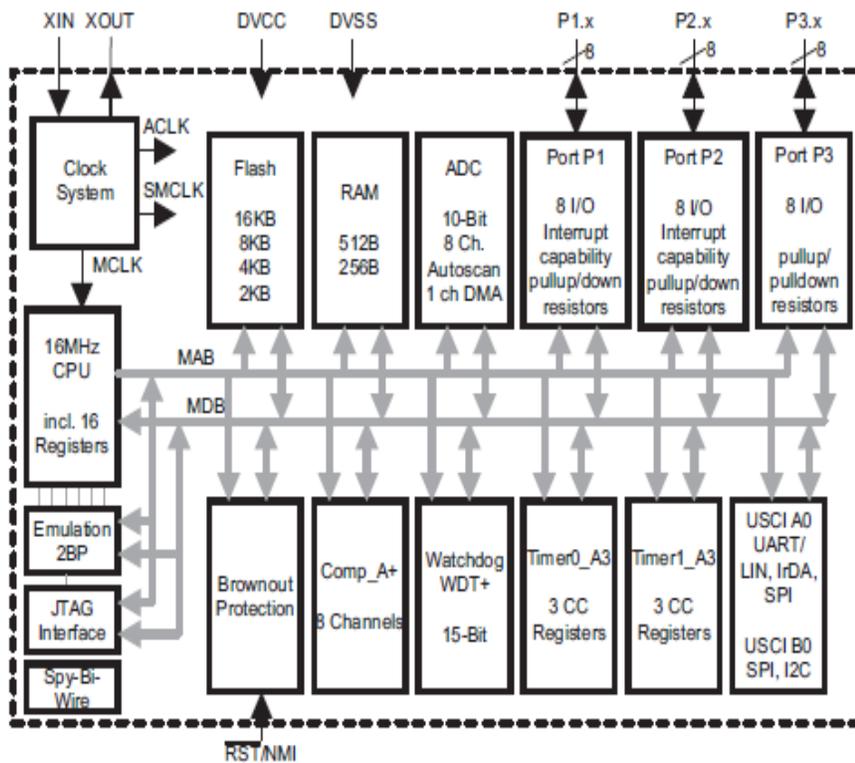


Figure 5. General architecture of MSP430G2x53.

3.2 Software Description

The software is developed using Code Composer Studio (CCS) Version V6 IDE²². The flow chart of the software program developed is shown in Figure 7. The code is compiled to create the hex file. This hex file is dumped onto the

Microcontroller MSP430G2553. The IC is removed from the Launch pad board and used in stand-alone mode. The IC is powered with +3.3V and program is executed.

The photograph of the total hardware developed in the present work is shown in the Figure 9.

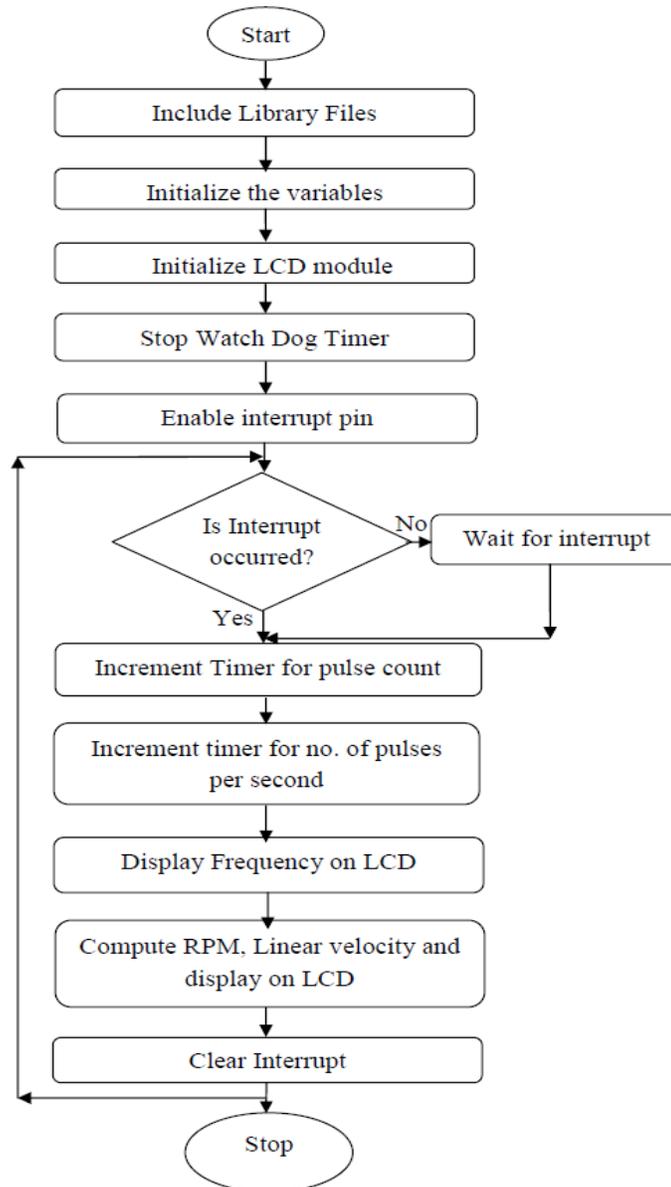


Figure 7. Flow chart of the software program.

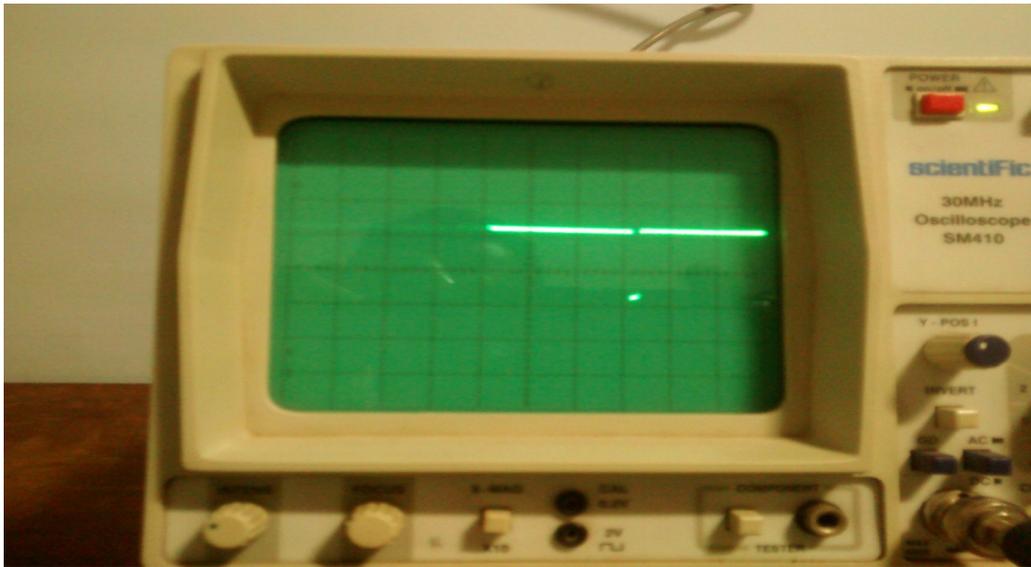


Figure 8. Photograph of the pulses displayed on CRO.

4. Methodology

A circular disc of radius 0.035 m is attached to the shaft of DC motor. Over the disc a small Neodymium magnet

of diameter 6mm is attached to the rim of the disc such that the south pole of the magnet faces the Hall Effect sensor. Hall Effect sensor (DRV5023-Q1) which acts as a switch is positioned in-line over the magnet without

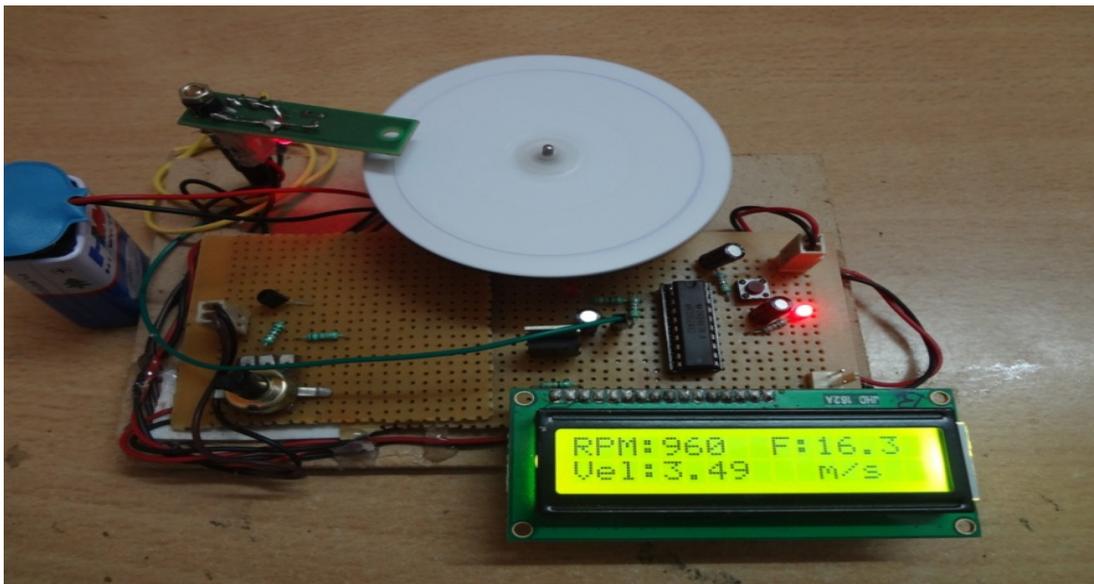


Figure 9. Photograph of the total hardware developed.

touching the magnet. Power is applied to the total system using a rechargeable 9V battery. The rotational speed of the motor and hence the disc can be controlled using the 10 k Ω potentiometer. When the magnet over the disc comes in-line with the Hall Effect sensor, the sensor produces a pulse, as shown in Figure 8. These pulses are fed to the microcontroller interrupt pin P1.3. Timer0 is incremented for pulse count. The number of pulses per second is counted. This gives the frequency of rotation. From the frequency value RPM and Linear velocity are computed using the equations (1) and (2). The experimental values are displayed on LCD module. Photograph of the measured values of RPM, Frequency and Linear velocity as displayed on LCD module is shown in Figure 9.

5. Result and Discussion

RPM values are measured for different speeds of motor by varying the applied voltage to the motor. The linearity of RPM measurement with applied voltage is tested by plotting a graph: RPM vs. applied voltage. The graph is shown in Figure 10. From the graph we can conclude that a good linearity of rpm measurement is obtained. Further, the frequencies of measurement using the developed system is compared with the frequencies measured with commercial frequency meter (PHILIPS PM6624D). Table 1 shows the comparison between these values. From the table it is clear that the frequencies measured with the

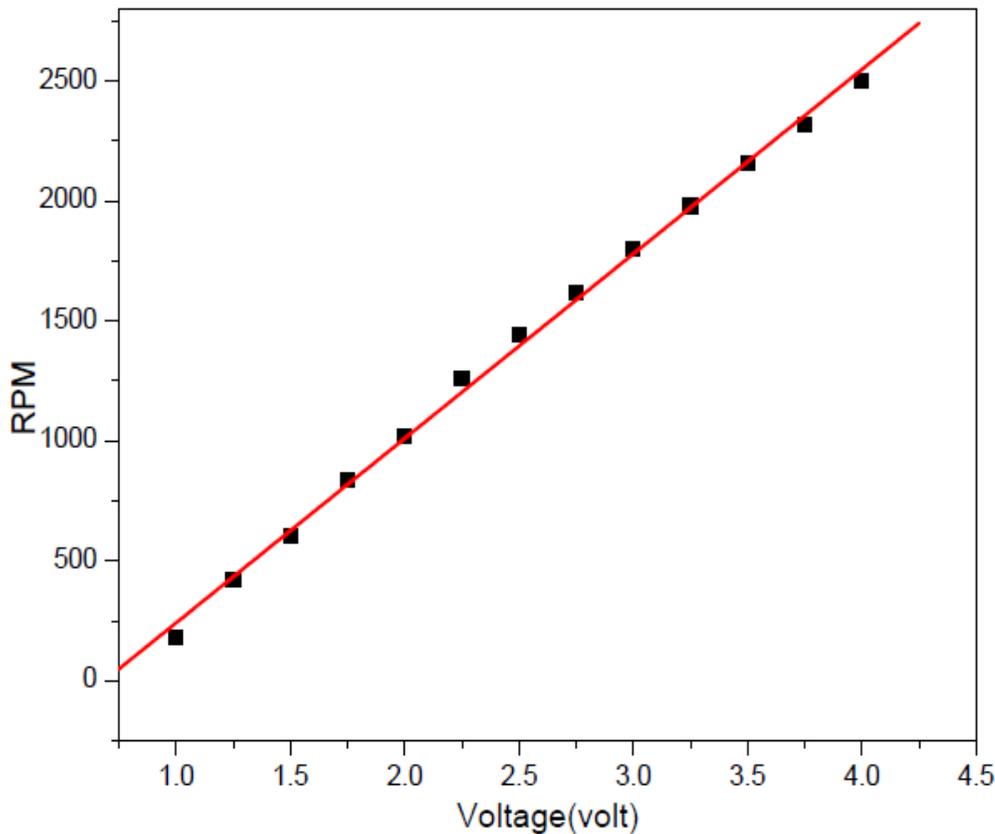


Figure 10. Graph of RPM vs. Voltage applied to the motor.

Table 1. Comparison of frequencies measured with developed system and commercial frequency meter (PHILIPS PM66240)

S.No.	RPM	Frequency (cycles/sec) (with developed System)	Frequency (cycles/sec) (with frequency meter PHILIPS PM66240)	Linear velocity measured (m/s) (with developed system)
1	300	5.0	5.0	1.1
2	600	10.1	10.0	2.22
3	900	15.2	15.0	3.34
4	1200	20.4	20.2	4.48
5	1500	25.4	25.2	5.58
6	1800	30.5	30.3	6.70
7	2100	35.6	35.4	7.82
8	2400	40.6	40.4	8.92
9	2700	45.7	45.3	10.04
10	3000	50.7	50.5	11.14

developed system and the frequencies measured with the standard frequency meter are in good agreement.

6. Conclusion

A portable and inexpensive linear velocity measurement system is developed using Hall Effect sensor DRV5023-Q1 and MSP430G2553 Microcontroller. The linearity in RPM measurement is tested and the frequencies of measurement are compared with the values obtained from standard frequency meter. This system with suitable control mechanism can be used for controlling the functionality of any rotating object.

7. Acknowledgment

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