Computerized Speed Measurement Technique using Magnetic Pickup Sensor

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Abstract

Speed measurements are very important task according to the large use of motors, generators and other rotating devices. Also for the high speed of rotation other than speed is a function of many other variables such as acceleration and speed etc….

This project helps to measure the speed of electrical machines which is very difficult to be measured directly.

The computer is used to measure the speed in revolution per minute (RPM) or revolution per second (RPS), very accurately by using a suitable circuit which is formed from, sensor, special designed electronic circuit and interface card (Hardware) with a built program (Software) to treat the data and to give the measured speed in a digital system.

استخدام الحاسوب في قياس السرعة باستخدام المتحسس Magnetic Pickup

الخلاصة

يعتبر قياس السرعة من المهمات الأساسية في المعدات الدوارة كالمحركات والمولدات الخ... حيث أن قياس السرعة هو داله لكثير من المتغيرات الأخر كالمسافة و التعجيل مثلا وكذلك للسرع العالية لهذه المكائن لغرض السيطرة عليها.ان هذا المشروع يساعد على قياس سرعة المكائن التي من الصعب قياس سرعتها بدقة بالطرق التقليدية آن قياس السرعة في وقتنا الراهن أصبح ضروريا جدا وذلك لكثره استخدام الأجهزة التي تحتوي على مكائن بصوره مباشرة وذلك لصعوبة الوصول أليها.

غاية هذا البحث هو استخدام الحاسوب لغرض قياس سرعة دوران أي ماكنه آو محرك بدقه عالية، ويتم ذلك باستخدام متحسس معين للحصول على اشاره تعتمد على سرعة الدوران ومن ثم إدخال هذه الأشاره إلى الحاسبة باستخدام دائرة تعشيق معينه بعد أجراء بعض التعديلات عليها.

نقوم بحساب سرعة الدوران باستخدام برنامج خاص داخل الحاسبة يعتمد على المؤقت الموجود في دائرة التعشيق.

1. Introduction

Various commercial sensors are available to measure the rotational position/speed of the engine crankshaft. The two primary sensor categories are optical and magnetic. Magnetic sensors such as magneto resistive are commonly used in practice to measure angular velocity. These sensors are employed because of its inexpensive, rugged, reliable, and no contacting device that need no calibration.

A magnetic pickup consists of a permanent magnet, a pole-piece and a sensing coil all encapsulated in a cylindrical case. An object (target) of iron, steel, or other magnetic material, passing closely by its pole-piece cause's distortion of the magnetic flux passing through the sensing coil and pole-piece. Which in turn generates a signal voltage? The magnitude of the signal voltage depends on the relative size of the magnetic target, its speed of approach, and how close it

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approaches [1]. Figure 1 (a) and (b) show the external and internal construction of the magnetic pickup, Speed measurement is needed for [4]:

1. Speed control.
2. Position control.
3. Distance measurements.
4. Acceleration measurements.
5. Other special applications.

2. System hardware

The designed system hardware consists of sensor, electronic circuit that reconditioned the signal of the sensor, interface card, and computer. Figure 3 shows the overall system configuration of the work.

2.1 The sensor

In this project magnetic pickup used to measure the speed of rotation part (RPM). The principle of operation depends on (Faradays law), it consist of a permanent magnet and coil, when a piece of metal moves in its magnetic field it cuts the magnetic flux and generate a pulse just like the principle of generators. The magnetic pickup is fixed on the fixed plate (un-rotating part) while a piece of metal (target) is fixed on the rotating part of the rotor. The target must be small and light as possible. When the rotor began to rotate, the target cut the magnetic field and generates a signal on the output of the magnetic pickup. The distance or air gap between the target and the magnetic pickup is between (0.5 – 2) mm and it depends on the type of magnetic pickup used, the output signal of magnetic pickup is shown in Figure 4 [4].

Amplitude of the output signal depend on speed of rotation (speed at which the target cut the magnetic flux), air gap, size and the shape of target itself [3].

The magnetic pickup used has the specification that its operating temperature ranges (-10 to +120 C^o), mass 380 gram, inductance 115 mH, DC resistance (220 to 260) Ω at 25 C^o [1].

The detected frequency in Hz is obtained from the relation:

$$f = \frac{RE}{60}$$

Where f = Detected frequency in Hz.

R = Number of revolution (RPM).

E = Number of targets.

Figure 3(a & b) are the results of two tests with different speed and sampling time. The first test with RPM=160 and sampling time equal to 1000 microseconds with target one is closer than target two to the sensor, while the second test RPM=375 and sampling time equal to 2000 microseconds also target one is closer than target two to the sensor[3].

2.2 Magnetic pickup signal conditioning circuit

The magnetic pickup signal must be converted to square waveform using appropriate electronic circuit. This square wave will be sensed by a personal computer using a suitable interface circuit.

A suitable electronic circuit will convert the actual signal from the magnetic pickup to a square wave. Figure 4(a &b) a simplified block diagram for the circuit used. The first block is a low pass filter, which pass the required signal frequency from magnetic pickup.

The second block is a comparator, in order to convert the sine wave to square wave. The output signal of the second part is shown in Figure 5, In order to get a pure square wave with 50% duty cycle the third block is added, which is a J-K flip flop [5].

Because of using JK flip-flop output signal frequency of the overall circuit will be half frequency of the system-input signal as shown in Figure 6. This problem will be solved in the program (software).

Magnetic pickup signal is in an analog form converted to digital form by the interface card. The signal then fed to the computer for later signal processing. Inside the computer, the Revolution Per Minute (RPM) will be measured from the magnetic pickup [3].

The above electronic circuit is very easy to implement, simple, components are available in markets and all over its operation is very efficient with low maintenance [5].

3. The interface card

The output signal from the magnetic pickup is in analog form. In order to feed these signals to a digital computer, a suitable interface card designed. The interface card contain analog to digital converter (ADC), ADC are widely used for data acquisition.

Digital computers use discrete values, but in the physical world everything is continuous (analog) such as temperature, pressure and velocity etc….

The 0804 IC is an ADC it works with (+5 volt) and has a resolution of 8 bits. The sampling rate can be controlled by these 8 bits with clock frequency 1.16 microseconds and connected to the parallel port.

The language of programming is written in visual basic. The complete flow chart of the interface card is shown in figure 7 [6].

4. The Simulator

In order to test the designed RPM meter system, i.e. the hardware and software, a simulator is implemented. The simulator as shown in Figure 8 consists of a DC motor operates from 12 volt with full load current about 8 Ampere. The speed of rotation can be varied from the DC power supply, which is designed specially for the simulator. Speed can be varied through a potentiometer on the output of the power supply. The motor is positioned vertically and fixed on small metal plate, which can be used to hold the magnetic pickup. This small metal plate is connected to the base of the simulator through three legs with springs to allow free movement of the motor.

The shaft is downward and with a small metal plate (Target) used to operate with the magnetic pickup.

The simulator is a general purpose one, so one can change the fan to another fan with different number of blades. Also one can change the number of targets to give more pulses per revolution (pinion) such application like turbine.

The simulator can be used for the following tests:

1. Variable Speed measurement tests.

2. Speed control tests.

3. Vibration control tests.

4. Tracking alignment control tests.

5. Position control tests.

6. Any other tests that need motor with variable speed.

5. The system software

This setup of work design and implemented in control laboratory in Al-Rasheed College of Engineering and science till now the hardware feeds the computer with magnetic pickup signal (square wave), the software of the program is written in Matlab and visual basic also it can be changed to any other language.

5.1 Correction of the magnetic pickup signal

Because a J-K flip-flop was used in the magnetic pickup signal conditioning circuit, the output signal frequency is dividing by two. When the signal frequency is divide by two means that there is one complete square wave for two revolutions for one target used on the main rotor.

In order to get the real signal frequency, the signal must be corrected to its original frequency, i.e. multiplied by two. The software does this. Figure 10 shows the magnetic pickup output after the J-K flip-flop (before correction) and the corrected magnetic pickup signal with frequency equal to the main rotor frequency (speed). Figure 10 shows the flowchart of this part. From now, all the measurement is done on the corrected signal of the magnetic pickup.

There is a difference in the amplitude of the square wave noticed before and after correction. The amplitude of the square wave is not important while the time interval of the square wave is very important to

measure speed so one can change the magnitude of the square wave by the program to any value.

So the difference noticed of the amplitude in figure 9 is just correction done in the software as a finishing matter.

5.2 Frequency and speed measurement

In order to measure the RPM (or frequency of rotation), the time of one cycle of magnetic pickup signal is evaluated, by knowing the time of one sample (which is set in the interface card) multiplied by the number of samples in one complete cycle.

Then measure the inverse of it so one gets the frequency or Revolution per Second (RPS). Multiplying this frequency by 60 one get the RPM. Figure 11 shows the flow chart of this part of the software.

6. Conclusions

Speed measurements are very important in many applications in our life's, other than speed is a function of many other variables such as acceleration and speed etc…. so many devices are used for speed measurements.

Many sensors available for speed measurements one of them is magnetic pickup, we used this one because it is very sensitive, rigid, no friction during its operation, simple and heavy duty.

This sensor give us signal according to the rotating of the machine this signal is then fed to computer through a suitable interface and by using program (software) one can measure the speed of the rotating machine. This project is used to measure the speed of a rotating machine, in the future we can make this sensor to measure linear speed by some advanced change in the hardware used.

7. References

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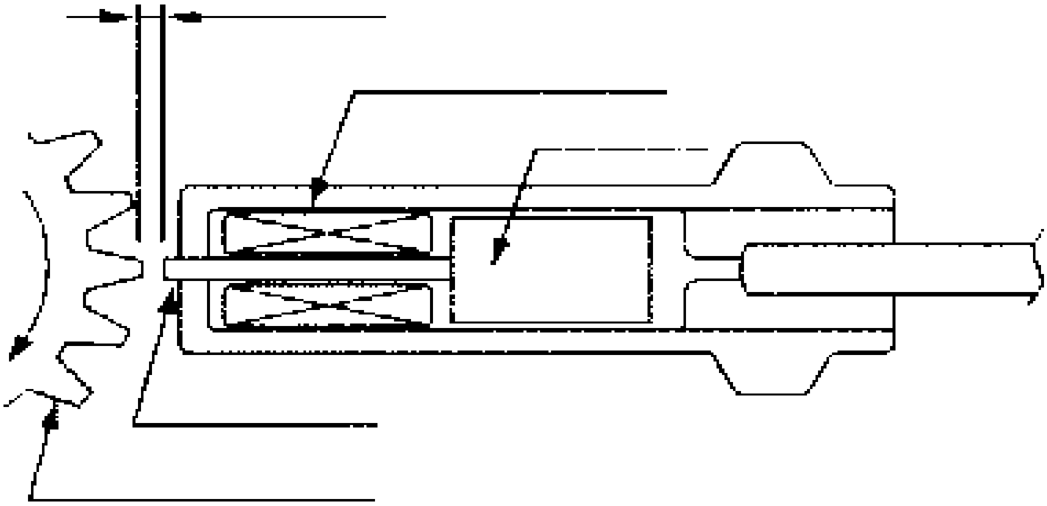


Figure (1-a) External construction of the magnetic pickup [2].

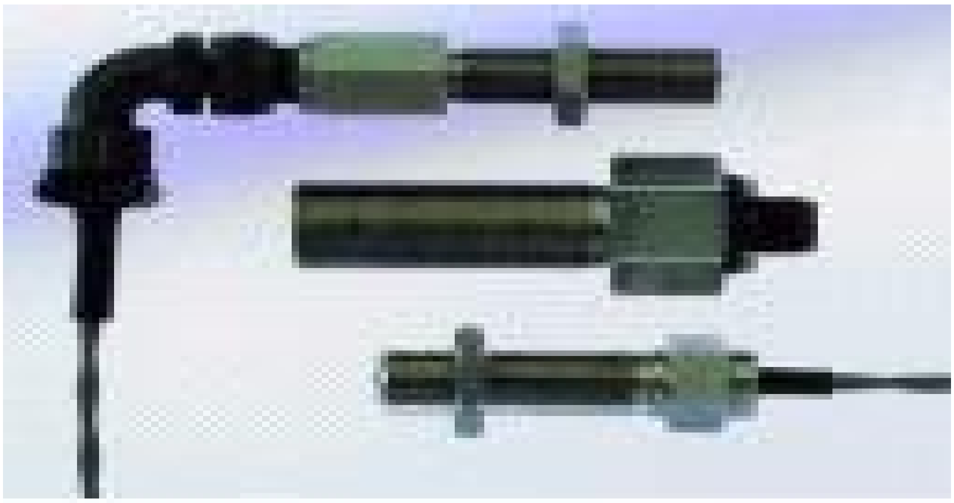


Figure (1-b) Inner construction of the magnetic pickup.

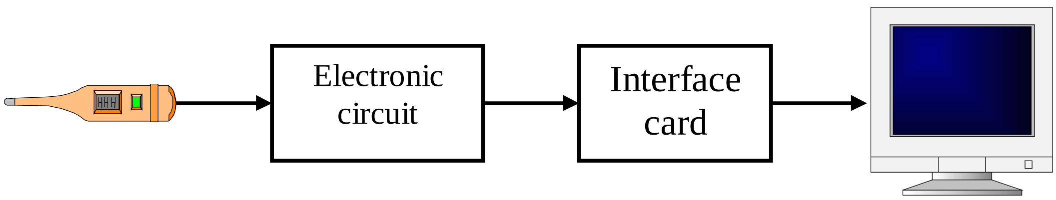


Figure (2) the all over system block diagram.

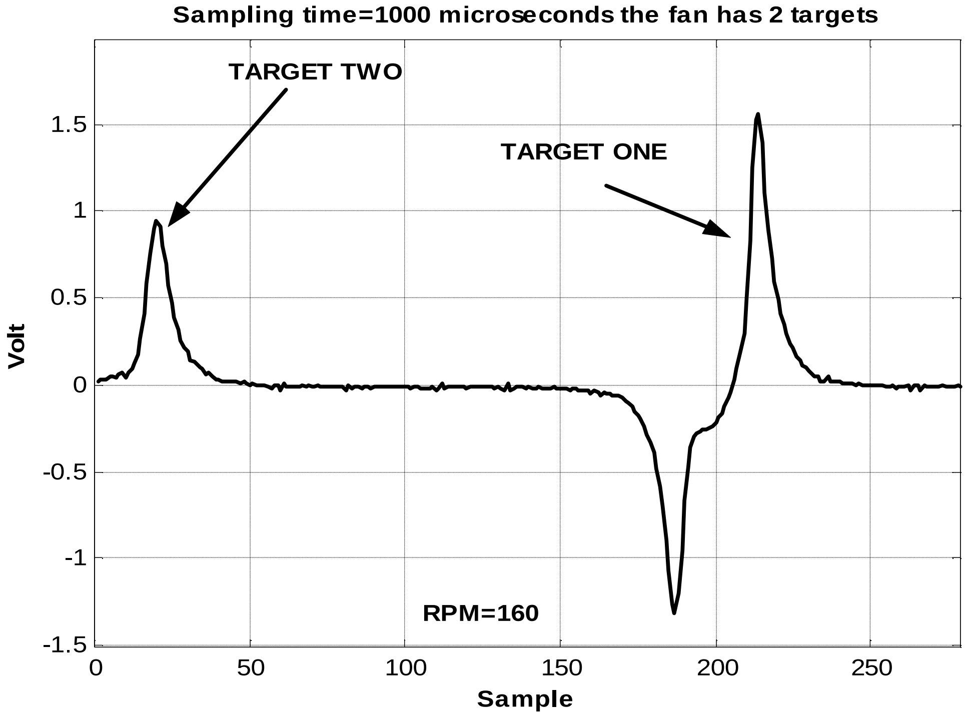
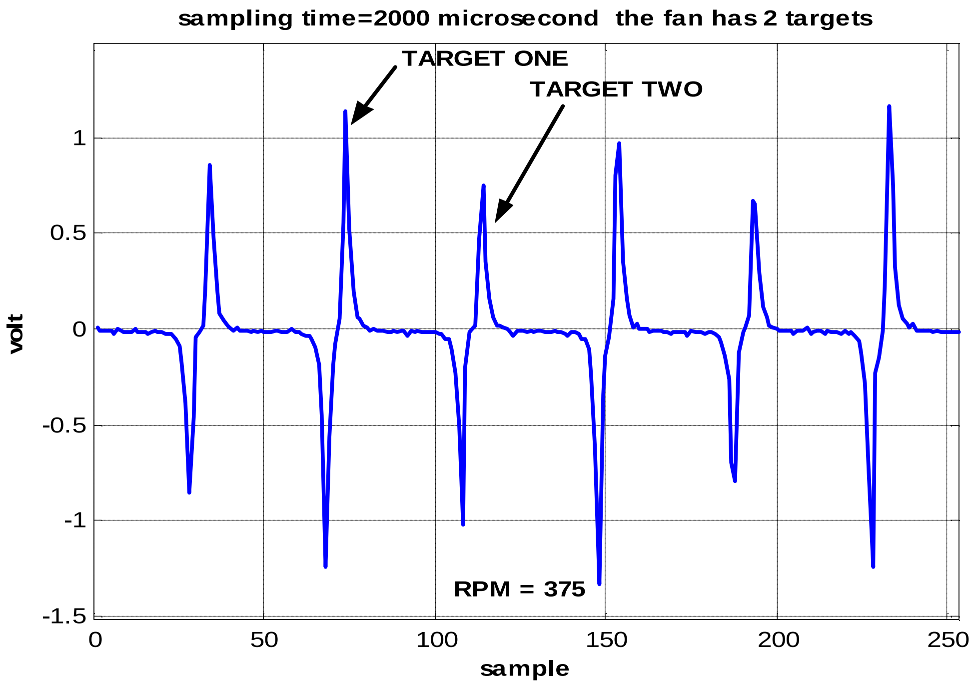


Figure (3-a) Magnetic pickup output signal test one.



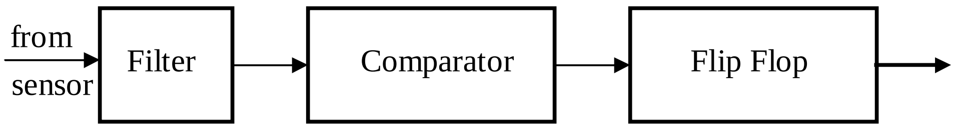


Figure (4-a) Magnetic pickup signal conditioning block diagram.

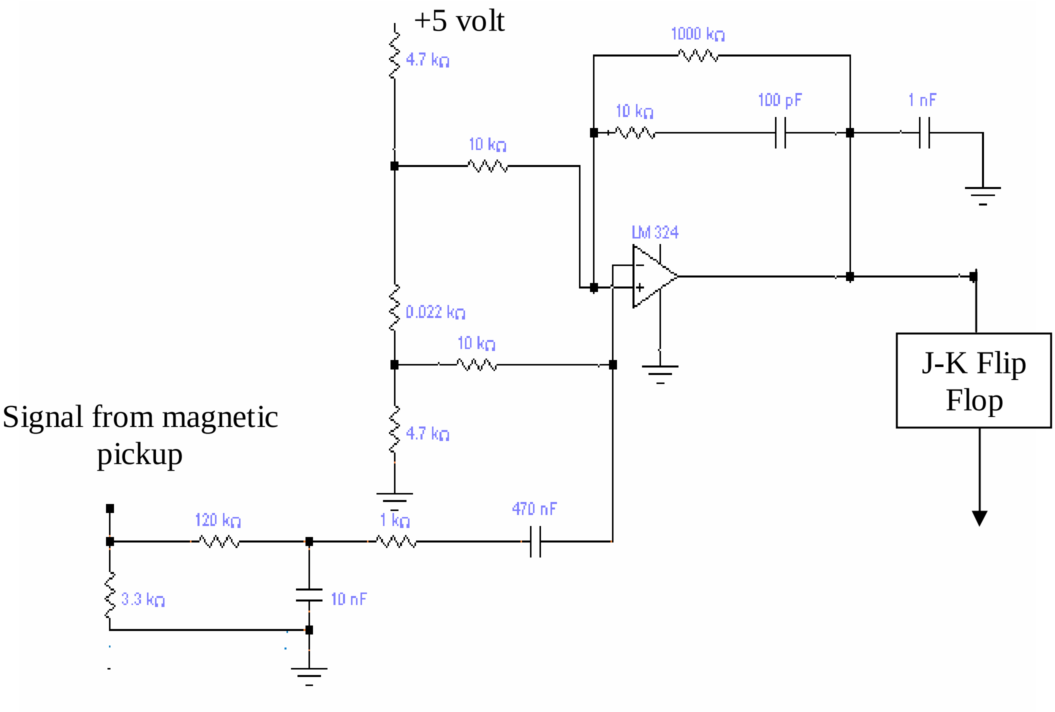


Figure (4-b) Circuit diagram for magnetic pickup signal conditioning.

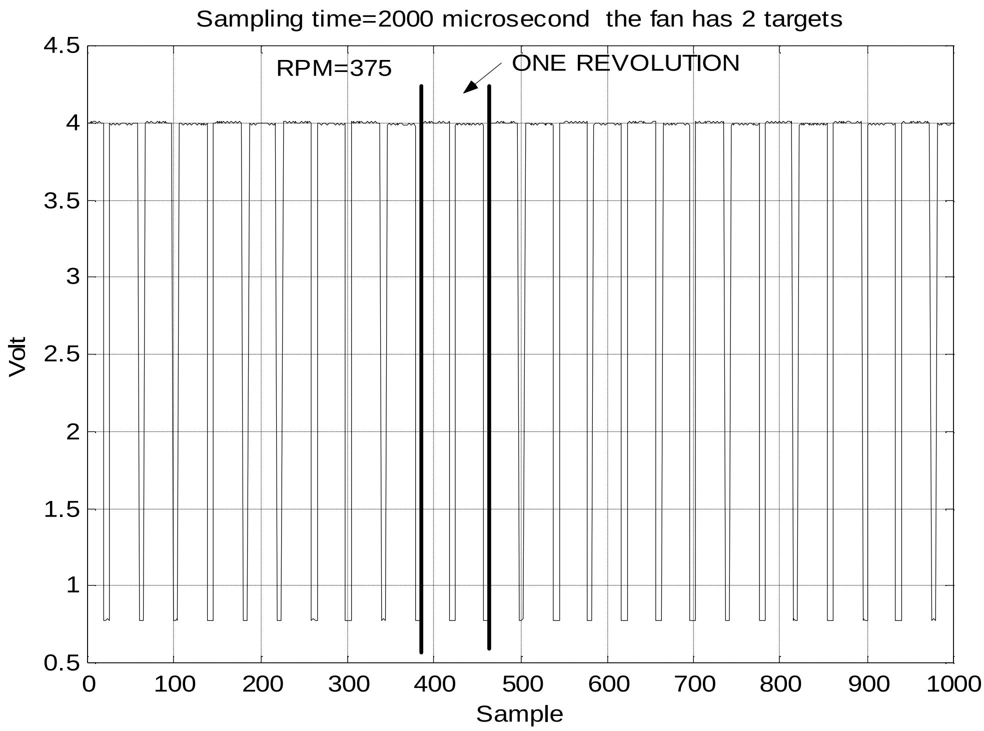


Figure (5) Output of the second part (comparator) of the magnetic pickup signal conditioning.

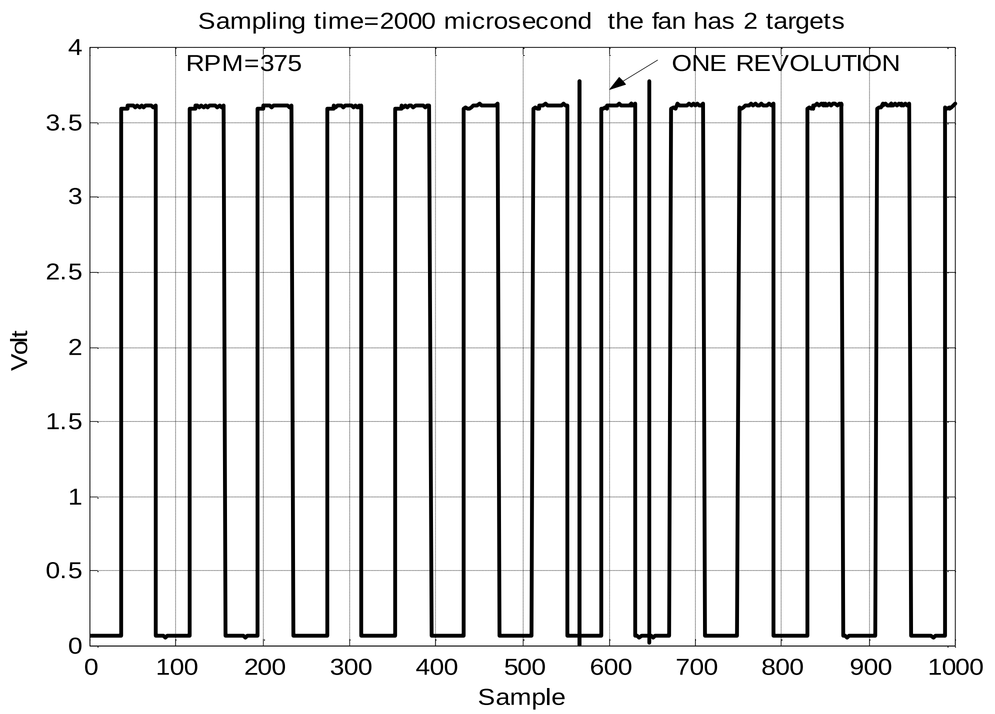


Figure (6) Magnetic pickup signal conditioning output.

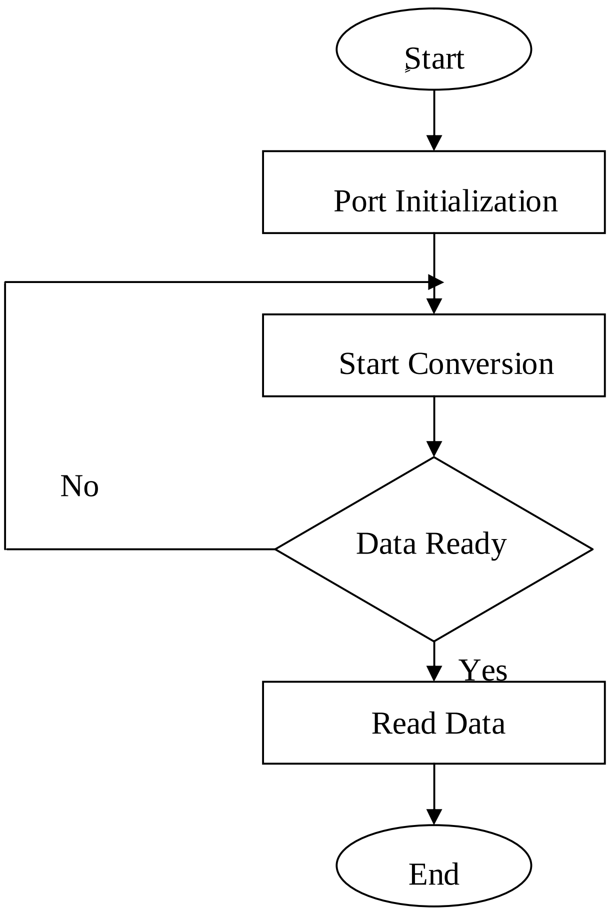


Figure (7) complete flow chart of the interface card.

Figure (8) The simulator.

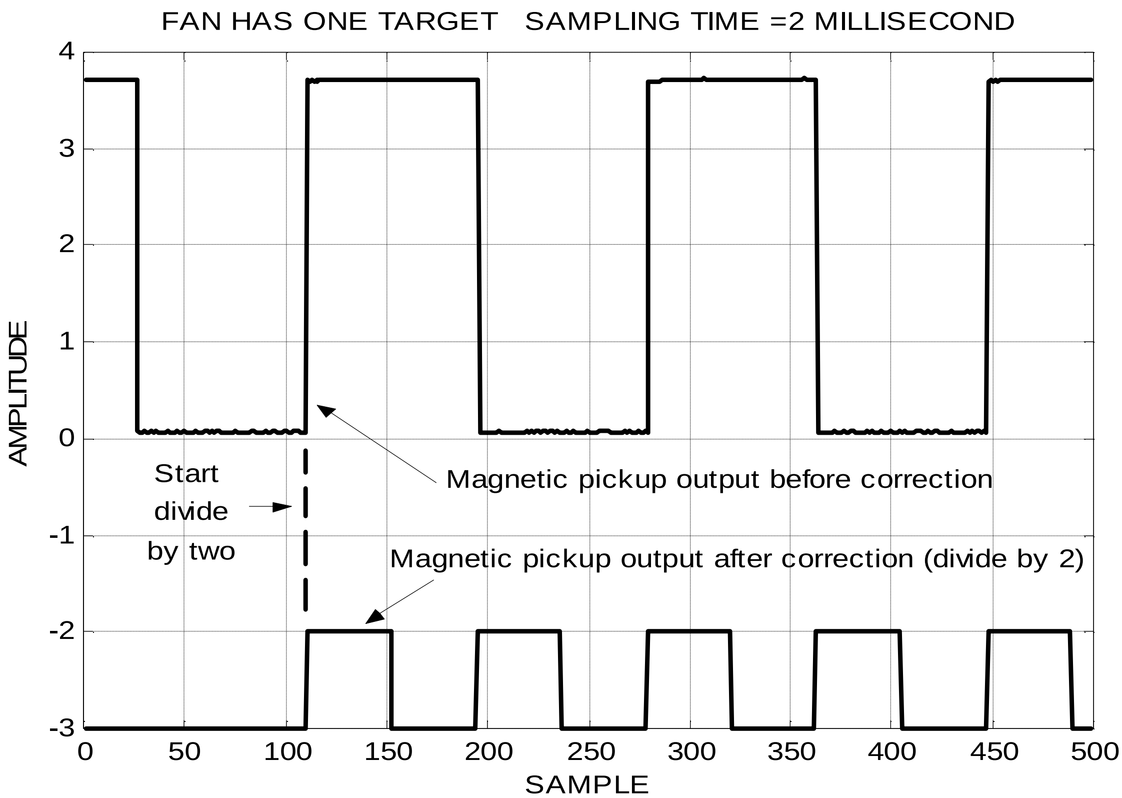


Figure (9) Magnetic pickup signal after correction.

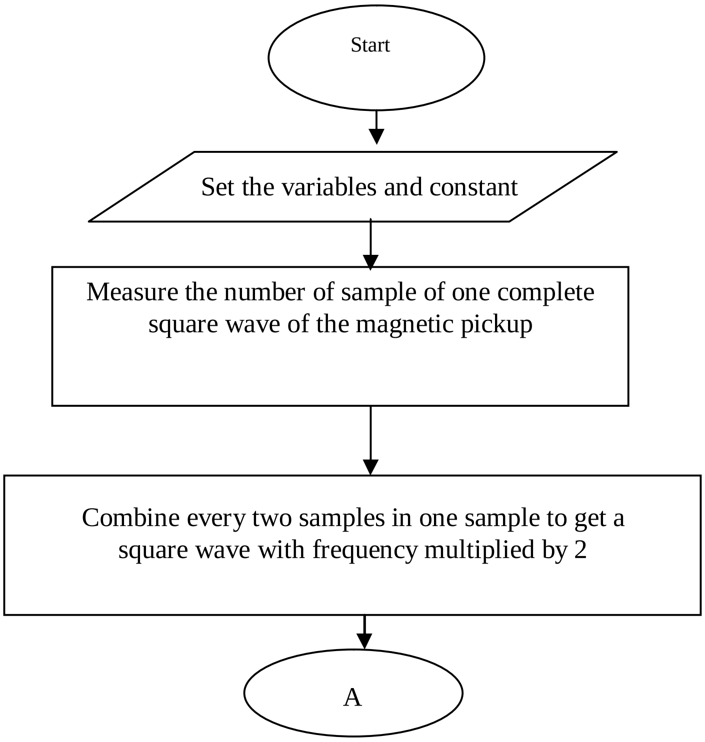


Figure (10) Flowchart of correction part.

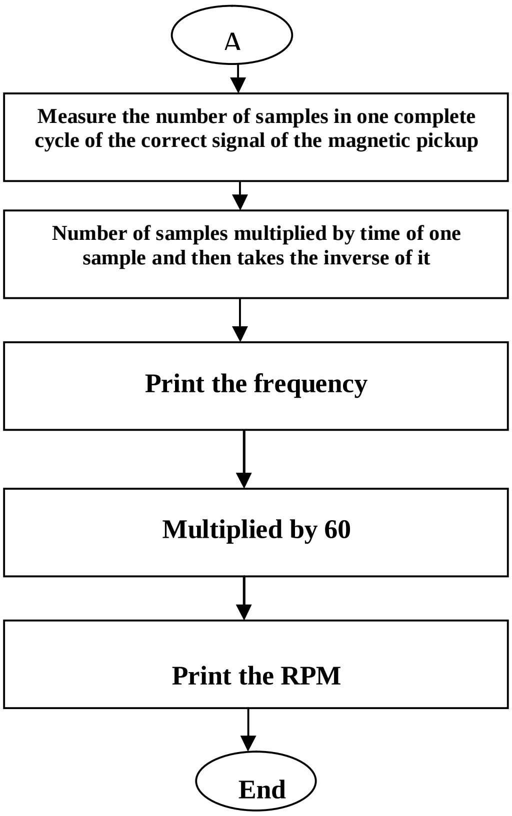


Figure (11) Flowchart for measuring frequency & RPM.