Sudan University of Science and Technology

College of Graduate Studies

Simulation of Bearing Working Conditions Monitoring System

محاكاة نظام مراقبة ظروف تشغيل المحامل

Thesis Submitted in Partial Fulfillment for the Requirements of the M.Sc. In Mechatronics Engineering

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الآيـــــــة

قال تعالي:

بسم الله الرحمن الرحيم

۞إِنَّ فِي خَلْقِ السَّمَاوَاتِ وَالْأَرْضِ وَاخْتِلَافِ اللَّيْلِ وَالنَّهَارِ وَالْفُلْكِ الَّتِي تَجْرِي فِي الْبَحْرِ بِمَا يَنفَعُ النَّاسَ وَمَا أَنزَلَ اللَّهُ مِنَ السَّمَاءِ مِن مَّاءٍ فَأَحْيَا بِهِ الْأَرْضَ بَعْدَ مَوْتِهَا وَبَثَّ فِيهَا مِن كُلِّ دَابَّةٍ وَتَصْرِيفِ الرِّيَاحِ وَالسَّحَابِ الْمُسَخَّرِ بَيْنَ السَّمَاءِ وَالْأَرْضِ لَآيَاتٍ لِّقَوْمٍ يَعْقِلُونَ۞

صدق الله العظيم

سورة البقرة الآية (164)

Dedication

TO

My Family

ACKNOWLEDGEMENT

Many thanks are due to Allah who owed me with health and courage to accomplish this work.

I would also like to express my deep sincere thanks, gratitude and appreciation to my supervisor**: Dr.** ***Gafer Abd AL Hamid*** for his instructive guidance, interest, continuous scientific support, supervision, encouragement, commitment, concern and interest that have been most valuable, I frankly confess that without his assistance this work would have never come to light.

Finally, I would like to take the opportunity to thank my parents and family for having supported me through the all project and studies.

Abstract

Machines are very important in modern society. The bearing compose a supreme component in the machine parts ,hence, many problems arise that minimize bearing life like high temperature, speed and excessive vibration.

In this research, electronic simulation system is developed to measure temperature, speed, and vibration in deep groove ball bearing. Hence, the system live alarms and sends signal to stop the machine when it exceeds one of three-designed value.

This system was tested in the simulation program which is considered an approximate imitation of the operation of process or system, that represents its operation over time, which showed a good possibility in measuring and control stopping the machine.

Thus, this simulation can serve as a risk prediction system in order to avoid such risks which might occur to the bearings.

المستخلص

الماكينات لها اهمية كبيرة في المجتمع المتحضر وتشكل المحامل المكون الابرز في اجزاء هذة الماكينات. وقد ظهرت العديد من المشاكل التي تقلل من عمر هذه المحامل مثل ارتفاع درجة الحرارة والسرعة والاهتزاز المفرط .

تم في هذا البحث عمل نظام محاكاة الكتروني لقياس درجة الحرارة والسرعة والاهتزاز في المحمل الكروي عميق المجري حيث يقوم هذا النظام باطلاق انذار ومن ثم ارسال اشارة لايقاف الماكينة عند تجاوزها الحد المسموح به من قبل المصمم لاحد القيم الثلاث .

تم اختبار النظام في برنامج محاكاة والذي يعتبر تقليدآ تقريبيا لتشغيل العملية او النظام ويمثل تشغيلها بمرور الزمن وقد اظهر امكانية جيدة في القياس والتحكم في ايقاف الماكينات وبذلك يمكن ان تكون هذة المحاكاة نظام تنبؤي بالاخطار التي يمكن ان تحدث للمحامل وتجنبها .

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Chapter One

Introduction

1-1 Preface

Due to the close relationship between motor system development and bearing assembly performance, it is difficult to imagine the progress of modern rotating machinery without consideration of the wide application of bearings. In addition, the faults arising in motors often linked with bearing faults. In many instances, the accuracy of the instruments and devices used to monitor and control the motor system is highly dependent on the dynamic performance of bearings. (Bo li, 2000)

This research investigates protecting bearings from hazards and faults caused by heat, vibration, and high speed and the importance of bearings in the machines as an important part in reducing friction and help in movement between two parts. Most companies and stations that use machines sustain a breakdown of the bearings which the cost of their replacement is very exorbitant and sometimes such damage or breakage engenders an impact in the machine.

1-2 Problem Statement

In the internal bearing system, the high temperature, high speed and high vibration in high load may fracture the exposing machine to damage and human live to peril, in spite of the fact that the control box of the feedback system is responsible for the stability of the machine as well as the stiffness and the damping of a suspension. Stiffness and damping varied widely within physical limits, and it adjusted to technical requirements with certain value.

1-3 Proposed Soluation

For the solution of the high temperature, high speed and high vibration problems in the bearing system the following steps should be taken. Firstly: a simulation system should be adopted to measure bearing temperature, speed and vibration. Secondly : a simulation feedback system should be made to control machine operation . Lastly, the software fire alarm issue an alert when the temperature, speed or vibration arrive to a critical point and stop the machine automatically.

1-4 Research Objectives

After identifying the problem and finding the appropriate solution for it by simulation and taking the required results, the following objectives should be achieved:

1-Simulation work to avoid operation in high operating conditions that cause damage and continuity of work in the case of ideal conditions.

2- Continuous monitoring of the system and high protection from heat, speed and high vibration.

3- Maintain and protect machines from fracture or fault.

1-5 Thesis outlines

The research is structured into five chapters. Chapter one is devoted to the introduction and objectives. Chapter two comprised the theoretical background and the third chapter dealt with the electronic system components selection. Chapter four included the results and discussion for simulation of the electronic system and finally chapter five comprised the conclusion and recommendations.

Chapter Two

Literature Review

2.1 Theoretical Background:

A bearing is a machine element that constrains relative motion to only the desired motion, and reduces friction between moving parts. For instance, the design of the bearing might provide for free linear movement of the moving part or for free rotation around a fixed axis; or, it might *prevent* a motion by controlling the vectors of normal forces that bear on the moving parts. Most bearings facilitate the desired motion by minimizing friction. Bearings are classified broadly according to the type of operation, the motions allowed, or to the directions of the loads (forces) applied to the parts. (Tandon, 1992).

Rotary bearings hold rotating components such as shafts or axles within mechanical systems, and transfer axial and radial loads from the source of the load to the structure supporting it. The simplest form of bearing and the *plain bearing*, consist of a shaft rotating in a hole. Lubrication often used to reduce friction. In the *ball bearing* and *roller bearing*, to prevent sliding friction, rolling elements such as rollers or balls with a circular cross-section are located between the races or journals of the bearing assembly. A wide variety of bearing designs exists to allow the demands of the application to correctly met for maximum efficiency, reliability, durability and performance. (kim, 1983)

The term "bearing" is derived from the verb "to bear", (Tandon, 1992) a bearing being a machine element that allows one part to bear (i.e., to support) another. The simplest bearings are bearing surfaces, cut or formed into a part, with varying degrees of control over the form, size, roughness and location of the surface. Other bearings are separate devices installed into a machine or machine part. The most sophisticated bearings for the most demanding applications are very precise devices; their manufacture requires some of the highest standards of current technology. (Mcfadden, 1984)

The invention of the rolling bearing, in the form of wooden rollers supporting, or bearing, an object being move is of great antiquity, and may predate the invention of the wheel. (kim P. , 1984)

Though it is often claim that the Egyptians used roller bearings in the form of tree trunks under sleds, this is modern speculation. (mathew, 1984) They depicted in their own drawings in the tomb of Djehutihotep . (Mcfadden, 1984) as moving massive stone blocks on sledges with liquid-lubricated runners, which would constitute a plain bearing. There are also Egyptian drawings of bearings used with hand drills. (kim P. , 1984)

The earliest recovered example of a rolling element bearing is a wooden ball bearing supporting a rotating table from the remains of the Roman Neman ships in Lake Neman, Italy. The wrecks dated to 40 BC. (KIM, 1984) (sunnersjo, 1978) Leonardo da Vinci incorporated drawings of ball bearings in his design for a helicopter around the year 1500. This is the first recorded use of bearings in an aerospace design. However, Agostino Ramelli is the first to have published sketches of roller and thrust bearings. An issue with ball and roller bearings is that the balls or rollers rub against each other causing additional friction, which can be reduce by enclosing the balls or rollers within a cage. Captured or caged ball bearing originally described by Galileo in the 17th century. (kim.a, 1984)

The first practical caged-roller bearing invented in the mid-1740s by horologist John Harrison for his H3 marine timekeeper. This uses the bearing for a very limited oscillating motion but Harrison also used a similar bearing in a truly rotary application in a contemporaneous regulator clock. (Mcfadden, 1984)

The first modern recorded patent on ball bearings was awarded to Philip Vaughan, a British inventor and ironmaster who created the first design for a ball bearing in Carmarthen in 1794. His was the first modern ball-bearing design, with the ball running along a groove in the axle assembly. (talien, 1965)

Bearings have played a pivotal role in the nascent Industrial Revolution, allowing the new industrial machinery to operate efficiently. For example, they saw use for holding wheel and axle greatly reduce friction over that of dragging an object by making the friction act over a shorter distance as the wheel turned.

The first plain and rolling-element bearings were wood closely followed by bronze. Over their history bearings have been made of many materials including ceramic, sapphire, glass, steel, bronze, other metals and plastic (e.g., nylon, polyoxymethylene, polytetrafluoroethylene, and UHMWPE) which are all used today.

Watch makers produce "jeweled" watches using sapphire plain bearings to reduce friction thus allowing more precise time keeping.

Even basic materials can have good durability. As examples, wooden bearings can still see today in old clocks or in water mills where the water provides cooling and lubrication.

The first patent for a radial style ball bearing awarded to Jules Surrey a Parisian bicycle mechanic, on 3 August 1869. The bearings then fitted to the winning bicycle ridden by James Moore in the world's first bicycle road race, Paris-Rouen, in November 1869. (meyer, 1980)

In 1883, Friedrich Fischer, founder of FAG, developed an approach for milling and grinding balls of equal size and exact roundness by means of a suitable production machine and formed the foundation for creation of an independent bearing industry.

The modern, self-aligning design of ball bearing attributed to Sven Wing Quist of the SKF ball-bearing manufacturer in 1907, when he awarded Swedish patent No. 25406 on its design.

Henry Timken, a 19th-century visionary and innovator in carriage manufacturing, patented the tapered roller bearing in 1898. The following year he formed a company to produce his innovation. Over a century, the company grew to make bearings of all types, including specialty steel and an array of related products and services.

Figure 2-1 Early Bearing

2.1.2 Bearing Types

There are at least six common types of bearing, each of which operates on different principles:

- Plain bearing, consisting of a shaft rotating in a hole. There are several specific styles: bushing, journal bearing, sleeve bearing, rifle bearing, and composite bearing.
- Rolling-element bearing, in which rolling elements placed between the turning and stationary races prevent sliding friction. There are two main types
- Ball bearing, in which the rolling elements are spherical balls
- Roller bearing, in which the rolling elements are cylindrical taper and spherical rollers
- Jewel bearing, a plain bearing in which one of the bearing surfaces is made of an ultra-hard glassy jewel material such as sapphire to reduce friction and wear.
- Fluid bearing, a noncontact bearing in which the load is supported by a gas or liquid,
- Magnetic bearing, in which the load is supported by a magnetic field
- Flexure bearing, in which the motion supported by a load element that bends. (eschmann, 1985)

2.1.3 Motions

Common motions permitted by bearings are:

- Radial rotation e.g. shaft rotation
- linear motion e.g. drawer
- spherical rotation e.g. ball and socket joint
- Hinge motion e.g. door, elbow, and knee.

2.1.4 Friction

Reducing friction in bearings is often important for efficiency, to reduce wear, to facilitate extended use at high speeds, and to avoid overheating and premature failure of the bearing. Essentially, a bearing can reduce friction by virtue of its shape, by its material, or by introducing and containing a fluid between surfaces or by separating the surfaces with an electromagnetic field. (choudhury, 1998)

- **By shape**, gains advantage usually by using spheres or rollers, or by forming flexure bearings.
- **By material** exploits the nature of the bearing material used. (An example would be using plastics that have low surface friction.)
- **By fluid** exploits the low viscosity of a layer of fluid, such as a lubricant or as a pressurized medium to keep the two solid parts from touching, or by reducing the normal force between them.
- **By fields** exploits electromagnetic fields, such as magnetic fields, to keep solid parts from touching.
- **Air pressure** exploits air pressure to keep solid parts from touching.

Combinations of these can even employed within the same bearing. Example of this is where the cage is made of plastic, and it separates the rollers/balls, which reduce friction by their shape and finish.

2.1.5 Loads

Bearing design varies depending on the size and directions of the forces that they are required to support. Forces can be predominately radial, axial (thrust bearings), or bending moments perpendicular to the main axis (sunnerjo, 1985).

2.1.6 Speeds

Different bearing types have different operating speed limits. Speed is typically specified as maximum relative surface speeds, often specified ft/s or m/s. Rotational bearings typically describe performance in terms of the product DN where D is the mean diameter (often in mm) of the bearing and N is the rotation rate in revolutions per minute.

Generally, there is considerable speed range overlap between bearing types. Plain bearings typically handle only lower speeds, rolling element bearings are faster, followed by fluid bearings and finally magnetic bearings, which limited ultimately by centripetal force overcoming material strength (sunnersjo, 1978).

2.1.7 Play

Some applications apply bearing loads from varying directions and accept only limited play or "slop" as the applied load changes. One source of motion is gaps or "play" in the bearing. For example, a 10 mm shaft in a 12 mm hole has 2 mm play.

Allowable play varies greatly depending on the use. As example, a wheelbarrow wheel supports radial and axial loads. Axial loads may be hundreds of Newton's force left or right, and it is typically acceptable for the wheel to wobble by as much as 10 mm under the varying load. In contrast, a lathe may position a cutting tool to ±0.002 mm using a ball lead screw held by rotating bearings. The bearings support axial loads of thousands of Newton in either direction, and must hold the ball lead screw to ±0.002 mm across that range of loads (sunnerjo, 1985).

Erich Franke invented and patented the wire race bearing in 1934. His focus was on a bearing design with a cross section as small as possible and which could integrate into the enclosing design. After World War II he founded together with

Gerhard Heydrich the company Franke & Heydrich KG (today Franke GmbH) to push the development and production of wire race bearings.

Richard Stribeck’s extensive research (choudhury, 1998) (wardle, 1983) on ball bearing steels identified the metallurgy of the commonly used 100Cr6 (AISI 52100) (sunnerjo, 1985) showing coefficient of friction as a function of pressure.

Designed in 1968 and later patented in 1972, Bishop-Wisecarver's co-founder Bud Wisecarver created vie groove bearing guide wheels, a type of linear motion bearing consisting of both an external and internal 90-degree vie angle.

In the early 1980s, Pacific Bearing's founder, Robert Schroeder, invented the first bi-material plain bearing which was size interchangeable with linear ball bearings. This bearing had a metal shell (aluminum, steel or stainless steel) and a layer of Teflon-based material connected by a thin adhesive layer. (volker, 1984)

Today ball and roller bearings used in many applications, which include a rotating component. Examples include ultra-high speed bearings in dental drills, aerospace bearings in the Mars Rover, gearbox and wheel bearings on automobiles, flexure bearings in optical alignment systems, bicycle wheel hubs, and air bearings used in Coordinate-measuring machines.

2.1.8 Interface Board

The SKT500 can actually being use with any of the microcontrollers in the AVR family (see the STK500 user guide). It allows a user to work with many different Atmel microcontrollers and easily gain access to their I/O pins. The STK500 has two serial port connectors (one for programming the devices and one as a spare RS232 port), a power supply switch and connector, eight LEDs and eight switches for general use, and various jumpers for configuring the board.

Figure 2 shows a top view of the STK500 interface board and the location of some of the hardware elements that you will use. (ATmel, 2001)

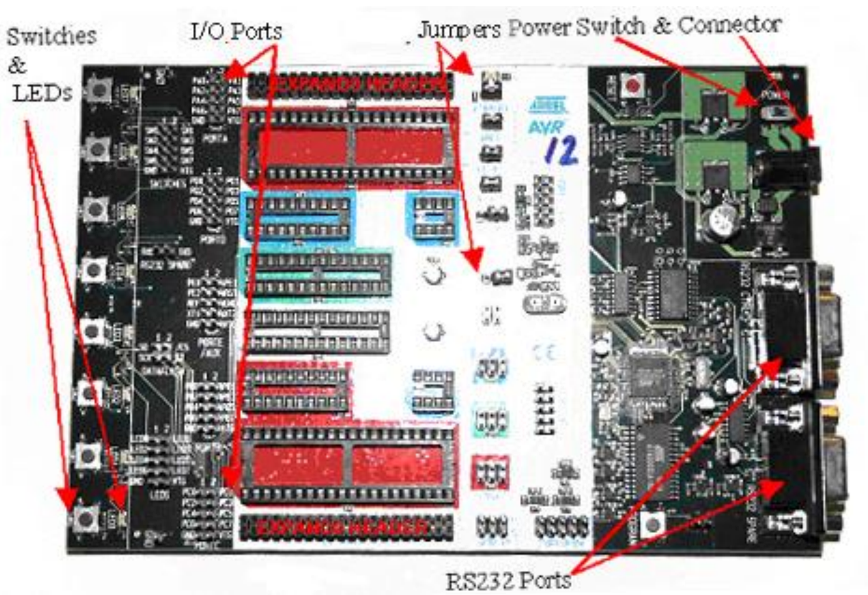
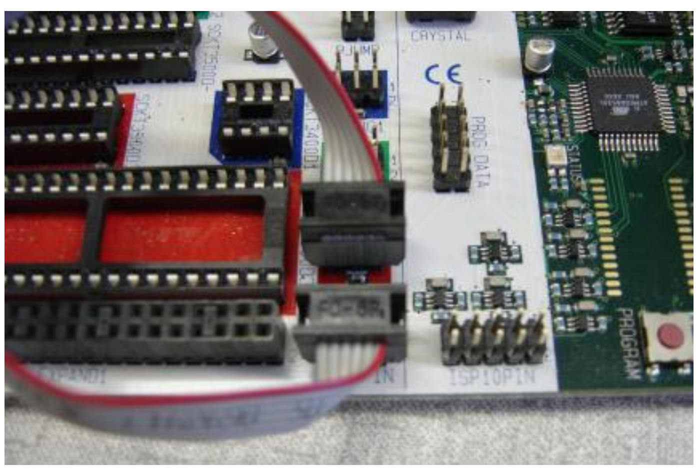


Figure 2-2 STK500 board

This is a 'universal' development board for AVR microcontrollers. Note the location of the features as indicated by the arrows.



Figur2-3 5-Pin board

5-Pin ISP ribbon cable connection for programming the ATmega16. Connect the ISP6PIN header set on the STK500 to the SPROG3 header set outlined in red using the 6-pin ISP ribbon cable. Make sure that you orient the red stripe on the cable, so that it connects to pin 1 on both header sets.

There are several ways can write, compile, and download a program to the ATmega16 microcontroller. There are many different text editors, compilers, and utilities available for many different languages (C, BASIC, assembly language, etc.). Some of these are free of charge, and some require a licensing fee to use them. In this class, use a freeware package of software tools named WinAVR (pronounced, “Whenever”). WinAVR has been installed on the computers in the Mechatronics Laboratory, but strongly encouraged to download it and install it on own computer, so can work with your microcontroller outside of the lab. Instructions for installing WinAVR given in Appendix A at the end of this document (ATmel, 2001)

2.1.9 Motor

Electric Motor Type Classification

In figure (2-4) shows types of electric motor which is consider an electrical machine that covert electrical energy into mechanical energy, it can be powered by direct current (DC) source, such as from batteries, motor or by alternative current (AC) source, such as a power grid, inverter or electrical generator .

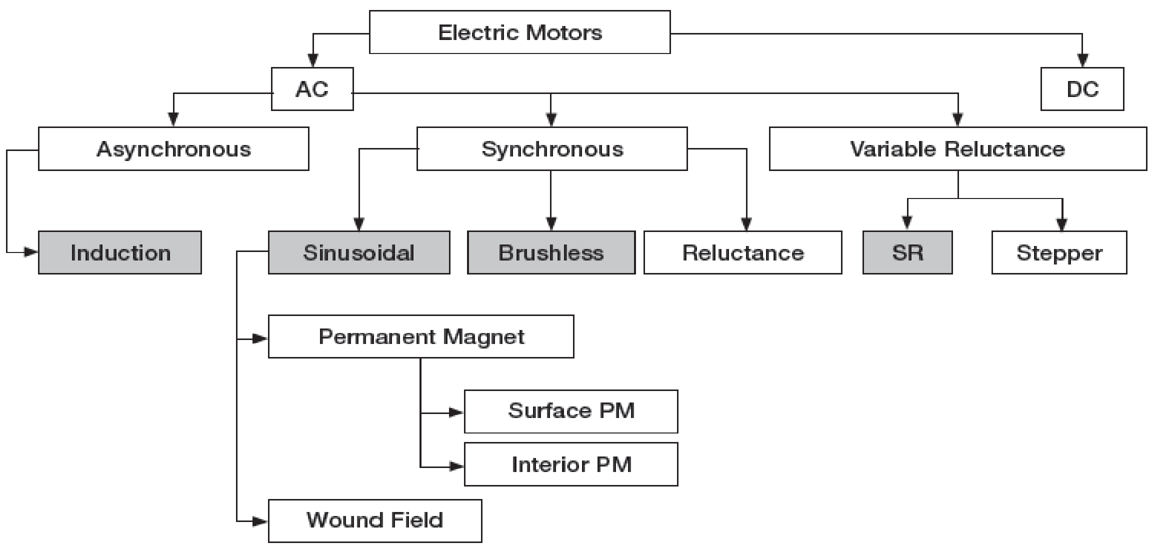


Figure (2-4) type of motor

2.1.9.2 Motor Control Application

Requirements

Minimize energy losses, Prevent environment pollution, Decrease acoustic noise and Power harmonics, Increase system performance versus- Cost ratio, Increase productivity, flexibility and robustness, Increase safety and reliability, Reduce system size and weight, Growth of digital control and reducing usage of analog components and total system cost. The rotating magnetic field principle, though commonly scientists such as Michael Faraday and James Clerk Maxwell in 1882 or thereabouts, employed cred to Nikola Tesla in the 1820s. Tesla, however, exploited the principle to design a unique two-phase induction motor in 1883. Michael von Dolivo-Dobrowlskyinvented the first modern three-phase "cage-rotor" in 1890. Introduction of the motor from 1888 onwards initiated what is known as the Second Industrial Revolution, making possible the efficient generation and long distance distribution of electrical energy using the alternating current transmission system, also of Tesla's invention (1888) (Mcfadden, 1984).

In figure (2-5) shows the bearing coding system which consider basic code consist of the bearing series, which indicates the type of bearing and bore number. The bearing series can be made up of letters and/or numbers that designate the construction, diameter series, and many cases the width series.

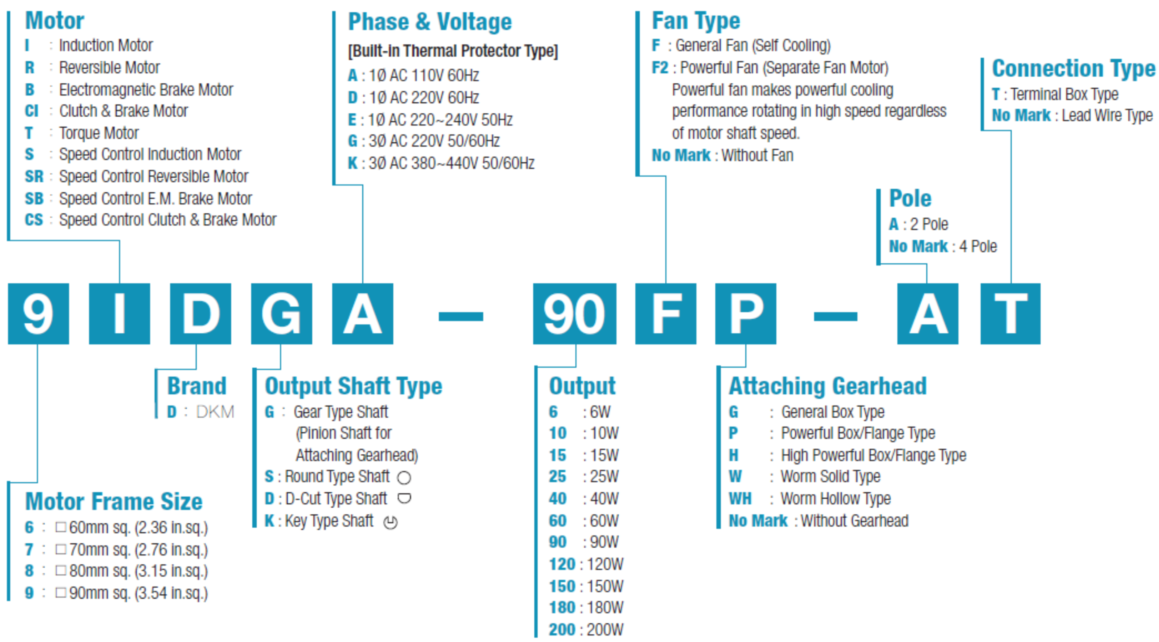


Figure 2-5 product coding system

2.1.10 Vibration Sensor

This module features an adjustable potentiometer, a vibration sensor, and a LM393 As comparator chip to give an adjustable digital output based on the amount of vibration. The potentiometer can adjusted to both increase and decrease the sensitivity to the desired amount. The module outputs a logic level high (VCC) when it is triggered and a low (GND) When it is not. Additionally an onboard LED turns on when the module triggered.

Features

The default state of the switch is close, Digital output Supply voltage: 3.3V-5V, On-board indicator LED to show the results, On-board LM393 chip, SW-420 based sensor, normally closed type vibration sensor, Dimension of the board: 3.2cm x 1.4cm.

Many Applications can created by measuring Vibration level, but sensing vibration accurately is a difficult job. This article describes about vibration sensor SW-420 and Microcontroller interface then it may help you to design effort less vibration measurement.

The vibration sensor SW-420 Comes with breakout board that includes comparator LM 393 and Adjustable on board potentiometer for sensitivity threshold selection, and signal indication LED.

The measurement of vibration is the most common method of assessing the mechanical status of machinery for condition monitoring purposes.

The measurements of vibration

The three parameters representing motion detected by vibration monitors are:

- Displacement
- Velocity
- Acceleration

These parameters can be measure by a variety of motion sensors and are mathematically related:

- Velocity is the first time derivative of Displacement.
- Acceleration is the first time derivative of Velocity0 (rajgur electronic, 2000)

They are many types of vibration sensor like

SW 420, piezo vibration sensor, Piezoelectric velocity sensors, CMSS 780C, CMSS 2100

Fundamental Cage Frequency:

$$F_C = \frac{1}{2} F_S \left(1 - \frac{D_b \cos\theta}{D_c}\right) \quad (2.1)$$

Ball Pass Outer Raceway Frequency:

$$F_{BPO} = \frac{N_B}{2} F_S \left(1 - \frac{D_b \cos\theta}{D_c}\right) \quad (2.2)$$

Ball Pass Inner Raceway Frequency:

$$F_{BPI} = \frac{N_B}{2} F_S \left(1 + \frac{D_b \cos\theta}{D_c}\right) \qquad (2.3)$$

Ball Rotational Frequency:

$$F_B = \frac{D_c}{2D_b} F_S \left(1 - \frac{D_b^2 \cos^2\theta}{D_c^2}\right) \qquad (2.4)$$

D_b is the ball diameter, D_c is the bearing cage diameter measured from one ball center to the opposite ball center, and θ is the contact angle of the bearing.

The geometrical structure of the bearing is

$D_b = 0.3125$ $\qquad D_c = 1.319$ $\qquad N_b = 8.$

When shaft rotational frequencies

$F_S = 32$ Hz (Bo li, 2000)

The contact angle in single row deep groove ball bearing 35°

After offsetting all the variable in above equation can find the total frequency F = 334 Hz

2-1-10-2 SW420 Vibration Sensor

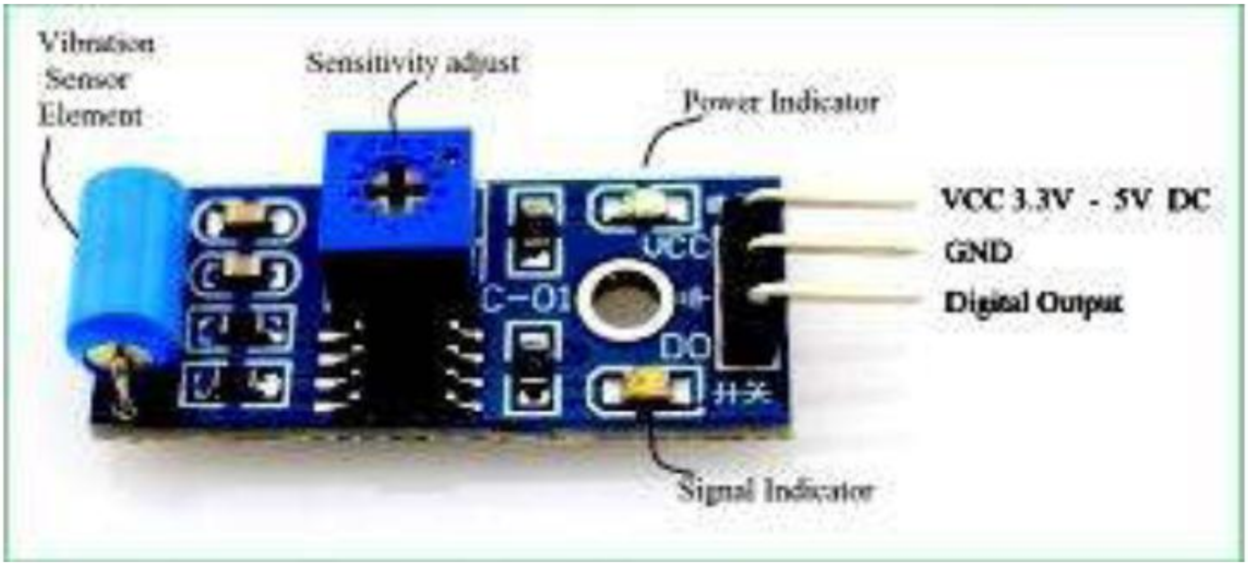


Figure 2-6 SW420 vibration sensor

This sensor module produce logic states depends on vibration and external force Applied on it. When there is no vibration, this module gives logic LOW output. When it feels vibration then output of this module goes to logic HIGH. The working bias of this circuit is between 3.3V to 5V DC. (rajgur, rajgur electronic, 2000)

2.1.11 Microcontroller

A microcontroller (MC) contains the main computer components: processor, program and data memories, input/output interfaces. Therefore, it can be name single-chip computer. The term “Microcontroller” tells that this device developed to control objects and processes. Because of this, the chip of MC contains various additional components as timers, A/D and D/A converters, voltage references, PWM generators, serial UART and USB interfaces etc. Constant improvement of MC parameters and low price allows penetrating the MCs into the various fields of human activity. We can find the microcontrollers in most of the devices that control, measure, calculate, or display information. As an example, the modern automobile can include up to 50 MCs. To interface with theenvironment, the additional components as various logical voltage level matching circuits, sensors, displays, connectors, switches, LEDs and so on should be use with the MC. Such a system, which includes MC or several MCs and additional components often, is name Microcomputer. Microcomputer in contrast to personal computer is very specialized developed for concrete purpose, e.g.

Control automobile engine or brakes or the hard disk drive of personal computer. Since such microcomputers embedded in other machinery, usually they called embedded systems or embedded computers. The variety of the embedded computers is extremely high; therefore, there are lot of laboratories and firms that develop the embedded computers. The time comes when most of electronic devices will based on the MCs, i.e. the engineers that develop or provide the service of electronics should have not only good knowledge of electronics hardware design but good knowledge of creating of MC programs, which usually called firmware, as well. (Baskys, 2012)

2.1.11.2 Types of microcontroller

In figure (2-7) shown the type of microcontrollers, they are characterized by their bits, memory architecture, memory/device and instruction set.

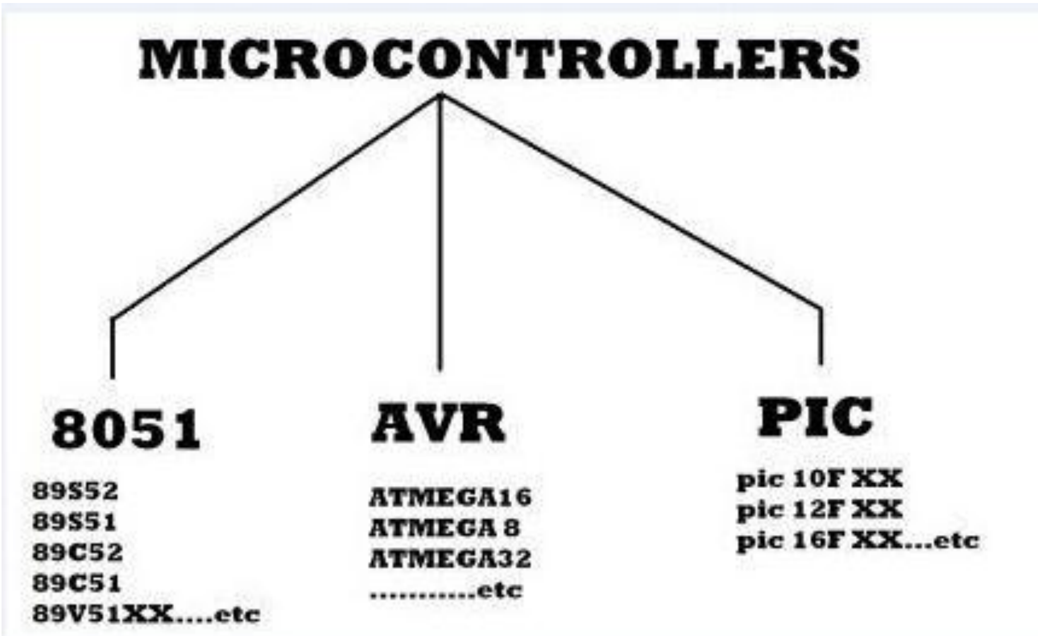


Figure 2-7 type of microcontroller

2-1-11-3 The ATmega16 Microcontroller

2.1. The ATmega16 microcontroller used in this lab is a 40-pin wide DIP (Dual in Line) package chip. This chip selected because it is robust, and the DIP package interfaces with prototyping supplies like solderless breadboards and solder-type perf-boards. This same microcontroller is available in a surface mount package, about the size of a dime. Surface mount devices are more useful for circuit boards built for mass production. Figure 1 below shows the 'pin-out' diagram of the ATmega16. This diagram is very useful, because it tells you where power and ground should be connected, which pins tie to which functional hardware, etc. (Atmel, 2002)

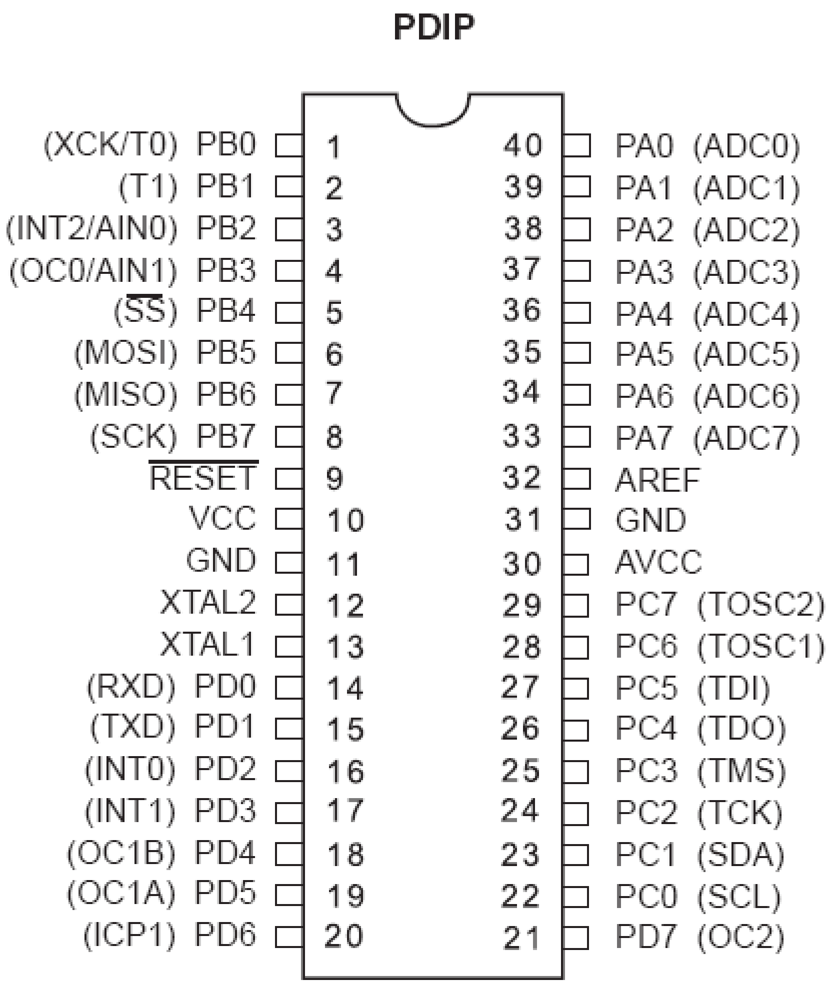


Figure 2-8 ATmega 16 pin -out diagram

2-1-12 Liquid-crystal display

A liquid-crystal display (LCD) is a flat-panel display or other electronically modulated optical device that uses the light-modulating properties of liquid crystals. Liquid crystals do not emit light directly, instead using a backlight or reflector to produce images in color or monochrome. LCDs are available to display arbitrary images (as in a general-purpose computer display) or fixed images with low information content, which can be displayed or hidden, such as preset words, digits, and 7-segment displays, as in a digital clock. They use the same basic technology, except that arbitrary images made up of a large number of small pixels, while other displays have larger elements.

Features:

Interface with either 4-bit or 8-bit microprocessor, Display data RAM, 80x8 bits (80 characters), Character generator ROM, 160 different 57 dot-matrix character patterns. Character generator RAM, 8 different user programmed 5 X7 dot-matrix patterns. Display data RAM and character generator RAM may accessed by the microprocessor, Numerous instructions, Clear Display, Cursor Home, and Display ON/OFF, Cursor ON /OFF, Blink Character, Cursor Shift, and Display Shift, Built-in reset circuit triggered at power ON, Built-in oscillator.

2-1-12-2 Liquid-crystal display (16x2)

Features:

5x8 dots with cursor, Built-in controller (KS 0066 or Equivalent), + 5V power supply (Also available for + 3V), 1/16 duty cycle, B/L to drive by pin (1), pin (2) or pin 15, pin 16 or A.K, (LED),N.V. optional for + 3V power supply (VISHAY, 2005)

Table 2-1 electrical specification LCD

ELECTRICAL SPECIFICATIONS						
ITEM	SYMBOL	CONDITION	STANDARD VALUE			UNIT
			MIN.	TYP.	MAX.	
Input Voltage	VDD	VDD = + 5V	4.7	5.0	5.3	V
		VDD = + 3V	+ 2.7	3.0	5.3	V
Supply Current	IDD	VDD = + 5V	–	1.2	3.0	mA
Recommended LC Driving Voltage for Normal Temp. Version Module Nor Temp/Wide Temp	VDD - V0	- 20 °C	–	–	–	V
		0°C	4.2	4.6	5.0	
		25°C	3.8	4.2	4.6	
		50°C	3.6	4.0	4.4	
		70°C	–	–	–	
LED Forward Voltage	VF	25°C	–	4.2	4.6	V
LED Forward Current	IF	25°C Array	–	130	260	mA
		Edge	–	20	40	
EL Power Supply Current	IEL	Vel = 110VAC:400Hz	–	–	5.0	mA

- ***LCD and Sizes***

There is still a wide variety of shapes and sizes available. Line lengths of 8, 16,20,24,32 and 40 characters are all standard, in one, two and four line versions.

- ***LCD Pin Description***

Most LCDs with 1 controller has 14 Pins and LCDs with 2 controller has 16 Pins (two pins are extra in both for back-light LED connections).

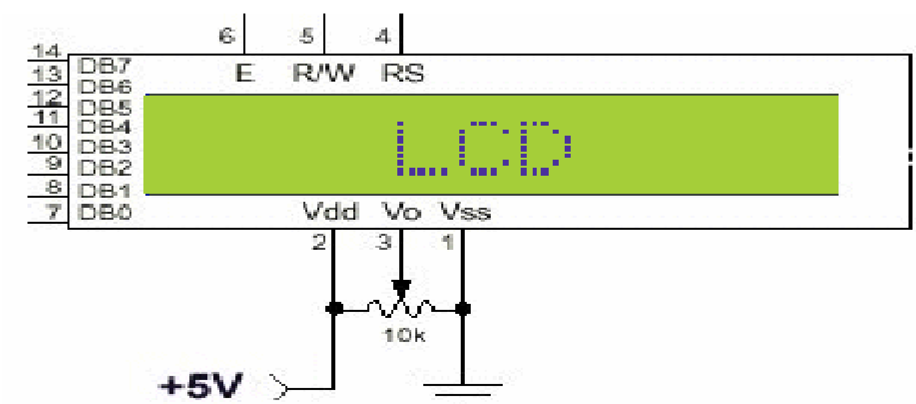


Figure 2-9 Bin Diagram of LCD 16*2

2.1.13 Ultrasonic Sensor

Ultrasonic transducers divided into three broad categories: transmitters, receivers and transceivers. Transmitters convert electrical signals into ultrasound, receivers convert ultrasound into electrical signals, and transceivers can both transmit and receive ultrasound.

In a similar way to radar and sonar, ultrasonic transducers used in systems, which evaluate targets by interpreting the reflected signals. For example, by measuring the time between sending a signal and receiving an echo the distance of an object can calculated. Passive ultrasonic sensors are microphones that detect ultrasonic noise that is present under certain conditions.

2-1-13-2 Applications and performance of Ultrasonic Sensor

Ultrasound can use for measuring wind speed and direction (anemometer), tank or channel fluid level, and speed through air or water. For measuring speed or direction, a device uses multiple detectors and calculates the speed from the relative distances to particulates in the air or water. To measure tank or channel level, the sensor measures the distance to the surface of the fluid. Further applications include: humidifiers, sonar, medical ultrasonography, burglar alarms, non-destructive testing and wireless charging.

Systems typically use a transducer that generates sound waves in the ultrasonic range, above 18 kHz, by turning electrical energy into sound, then upon receiving the echo turn the sound waves into electrical energy, which can be measured and displayed.

2-1-13-3 Svenska kullagerfabriken factory speed sensor

SKF sensor bearing units, which integrate bearing function with sensor electronics, are capable of detecting shaft speed and acceleration, direction of rotation, and angular position. These units have a robust and simple design, offering high signal accuracy and reliability, compactness, and ease of assembly.

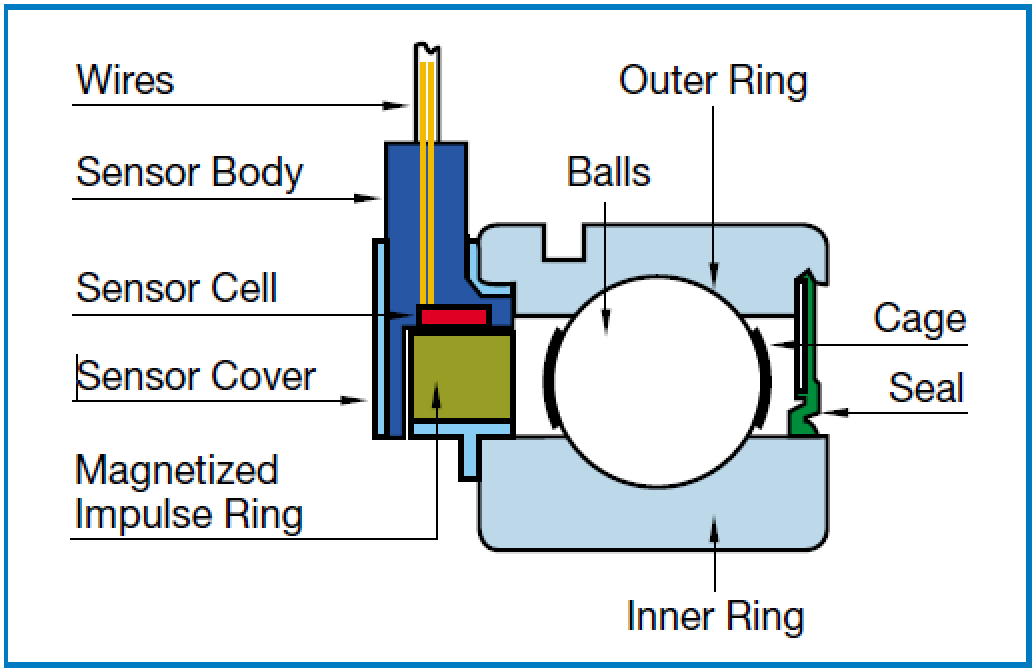


Figure 2-10 speed sensor

Sensor bearing units are key components in the progression of industrial vehicle technology. Sensor bearings used in the electronic steering systems of industrial vehicles can replace heavy, expensive mechanical and hydraulic steering systems. Other applications for this bearing include height and position control systems. Using these systems, the operator can monitor the exact height of the load or preset load height with the touch of a button.

2-1-13-4 Dimensions & Assembly Speed Sensor

Standard SKF sensor bearings based on ISO dimensions. Existing shafts and housings can therefore use without modification. However, an additional 6mm of axial clearance must left free around the pitch diameter of the bearing.

Temperature Range: -40° to 120 °C, peak 150 °C

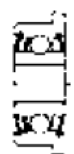
Supply Voltage: 3.8 to 24 Volts

Output Current: of each signal wire (when transmitter is "ON") limited to 20mA by the load resistors

Conforms to EMC European norm EN-50082-2 1995 (SKF, 2001)

Table 2-2 Micro Bearing

MICRO BEARING (INCH SERIES)

OPEN TYPE								DOUBLE SHIELD TYPE								
					 Flanged Outer Ring				 Flanged Outer Ring							
Bearing No.	Boundary Dimensions				Bearing No. Flange Type	Boundary Dimensions		Bearing No.	Boundary Dimensions			Flange Width	Basic Load Ratings (lbs)		Limiting Speeds (RPM)	
	Bore	O.D.	Width	Min. Chamfer		Flange O.D.	Flange Width		Width	Bearing No. Flange Type w/Shields	OD		C Dynamic	Co Static	Grease	Oil
R01	0.0400	0.1250	0.0469	0.003	—	—	—	—	—	—	—	—	22	6	110,000	130,000
R0	0.0469	0.1562	0.0625	0.003	FLR0	0.203	0.013	RA0ZZA	0.0937	FLRA0ZZA	0.203	0.031	36	10	93,000	110,000
R1	0.0550	0.1875	0.0781	0.003	FLR1	0.234	0.023	RA1ZZA	0.1094	FLRA1ZZA	0.234	0.031	42	13	81,000	95,000
R1-4	0.0781	0.2500	0.0937	0.003	FLR1-4	0.296	0.023	RA1-4ZZA	0.1406	FLRA1-4ZZA	0.296	0.031	63	20	67,000	79,000
R133	0.0937	0.1875	0.0625	0.003	FLR133	0.234	0.018	RA133ZZA	0.0937	FLRA133ZZA	0.234	0.031	28	9.5	73,000	85,000
R1-5	0.0937	0.3125	0.1094	0.005	FLR1-5	0.359	0.023	RA1-5ZZA	0.1406	FLRA1-5ZZA	0.359	0.031	96	34	56,000	66,000
R144	0.1250	0.2500	0.0937	0.003	FLR144	0.296	0.023	RA144ZZA	0.1094	FLRA144ZZA	0.296	0.031	64	22	59,000	70,000
R2-5	0.1250	0.3125	0.1094	0.003	FLR2-5	0.359	0.023	RA2-5ZZA	0.1406	FLRA2-5ZZA	0.359	0.031	126	40	54,000	63,000
R2-6	0.1250	0.3750	0.1094	0.005	—	—	—	RA2-6ZZA	0.1406	—	—	—	144	50	49,000	58,000
R2	0.1250	0.3750	0.1562	0.012	FLR2	0.440	0.030	R2ZZA	0.1562	FLR2ZZA	0.440	0.030	144	50	49,000	58,000
RA2	0.1250	0.5000	0.1719	0.012	—	—	—	RA2ZZ	0.1719	—	—	—	258	89	43,000	51,000
R155	0.1562	0.3125	0.1094	0.003	FLR155	0.359	0.023	RA155ZZA	0.1250	FLRA155ZZA	0.359	0.036	76	30	51,000	60,000
R156	0.1875	0.3125	0.1094	0.003	FLR156	0.359	0.023	RA156ZZA	0.1250	FLRA156ZZA	0.359	0.036	89	32	49,000	58,000
R166	0.1875	0.3750	0.1250	0.003	FLR166	0.422	0.023	R166ZZA	0.1250	FLRA166ZZA	0.422	0.031	160	60	46,000	55,000
R3	0.1875	0.5000	0.1562	0.012	—	—	—	—	0.1875	—	—	—	295	110	41,000	48,000
RA3	0.1875	0.5000	0.1960	0.012	FLRA3	0.565	0.042	RA3ZZ	0.1960	FLRA3ZZ	0.565	0.042	295	110	41,000	48,000
R168	0.2500	0.3750	0.1250	0.003	FLR168	0.422	0.023	R168ZZA	0.1250	FLRA168ZZA	0.422	0.036	60	31	43,000	51,000
R188	0.2500	0.5000	0.1250	0.005	FLR188	0.547	0.023	RA188ZZA	0.1875	FLRA188ZZA	0.547	0.045	186	84	39,000	46,000
R4	0.2500	0.6250	0.1960	0.012	FLR4	0.690	0.042	R4ZZ	0.1960	FLR4ZZ	0.690	0.042	335	136	36,000	43,000
R6	0.3750	0.8750	0.2812	0.016	FLR6	0.989	0.062	R6ZZ	0.2812	FLR6ZZ	0.989	0.062	526	199	31,000	37,000

In table (2-2) shown the bearing numbers are alphanumeric combination that indicates the bearing type, boundary dimension, internal clearance, basic load, limiting speeds on open type and double shield type of bearing

2-1-14 LM35 Temperature Sensor

The LM35 series are precision integrated-circuit temperature sensors, whose output voltage is linearly proportional to the Celsius (Centigrade) temperature. The LM35 thus has an advantage over linear temperature sensors calibrated in° Kelvin, as the user is not required to subtract a large constant voltage from its output to obtain convenient Centigrade scaling. The LM35 does not require any external calibration or trimming to provide typical accuracies of ±1⁄4°C at room temperature and ±3⁄4°C. over a full −55 to +150°C temperature range. Low cost assured by trimming and calibration at the water level. The LM35's low output impedance, linear output, and precise inherent calibration make interfacing to readout or control circuitry especially easy. It can be used with single power supplies, or with plus and minus supplies. As it draws only 60 µA from its supply, it has very low self-heating, less than 0.1°C in still air. The LM35 rated to operate over a −55° to +150°C temperature range, while the LM35C rated for a −40° to +110°C range (−10°with improved accuracy). The LM35 series is available packaged in hermetic TO-46 transistor packages, while the LM35C, LM35CA, and LM35D are also available in the plastic TO-92 transistor package. The LM35D is also available in an 8-lead surface mount small outline package and a plastic TO-220 package. (NATIONAL, 2000)

In figure(2-11) is shows Typical applications of LM35 temperature sensor

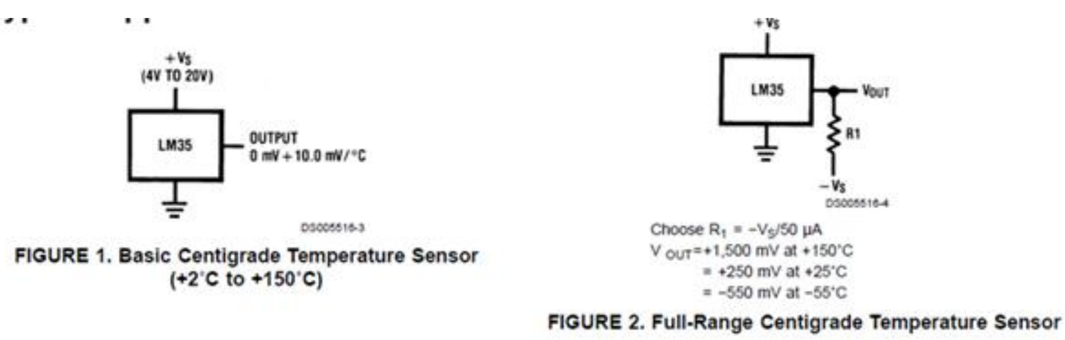


Figure 2-11 LM35 Temperature Sensor

2-1-15 Driver ULN2003

The ULN2003A us to prevent reverse currents and enlarge current from micro and an array of seven NPN Darlington transistors capable of 500 mA, 50 V output. It features common-cathode fly back diodes for switching inductive loads. It can come in PDIP, SOIC, SOP or TSSOP packaging.[1][2] In the same family are ULN2002A, ULN2004A, as well as ULQ2003A and ULQ2004A, designed for different logic input levels. (ST, 2002)

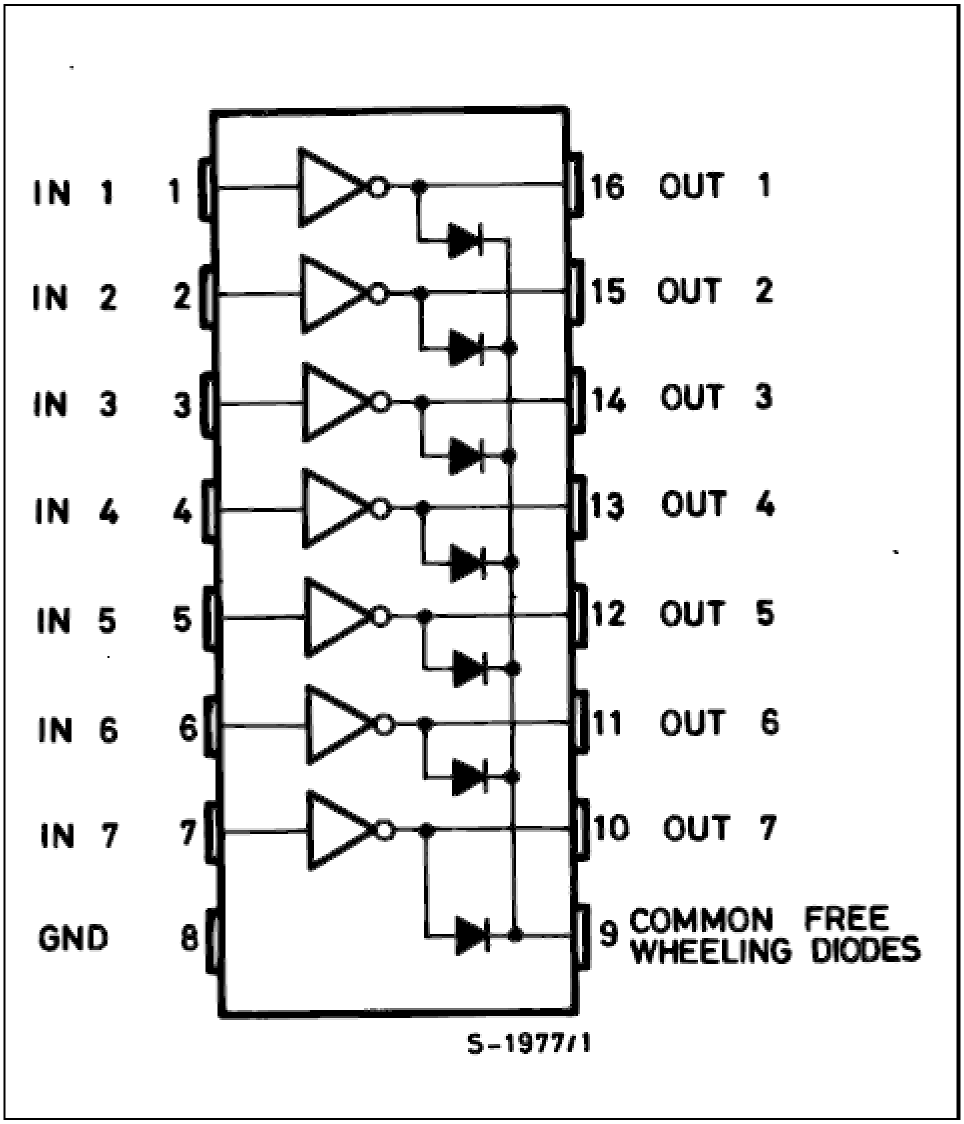


Figure 2-12 ULN 2003 Driver

2-2 Related Works

In 2016, Sohaib clarify that Speed control of DC motor is very critical in most of the industrial systems where accuracy and protection are of essence. The simulations of Proportional Integral Derivative Controller (PID) on a 16-bit PIC 24F series microcontroller for speed control of a DC motor in the presence of load torque presented. Linear quadratic regulator (LQR) technique has tuned the PID gains, and then it implemented on microcontroller using MPLAB, and finally simulated for speed control of DC motor in Proteus Virtual System Modeling (VSM). Software Proteus has built in feature to add load torque to DC motor so simulation results have presented in three cases speed of DC motor controlled without load torque, with 25% load torque and with 50% load torque. In all three case, PID effectively controls the speed of DC motor with minimum steady state error. (sohaib, 2016)

In addition, Akhand study Rolling element that play crucial role in the functioning of rotating machinery. Recently, the use of diagnostics and prognostic methodologies assisted by artificial intelligence tools such as artificial neural networks support vector machines etc. have increased for assessing the health of rolling element bearing. The effectiveness of these approaches largely depends upon the quality of features extracted from the bearing signal. Keeping this in mind the authors have presented the various signal processing methods applied to the fault the objective of giving an opportunity to the examiner to decide and select the best possible signal analysis method as well as the excellent defect representative features for future application in the prognostic approaches. (akhand, 2016)

In 2014, Patel investigated vibrations generated by deep groove ball bearings having multiple defects on races have studied in this paper. The vibrations are analyzed in both time and frequency domains. The equations for time delay between two or more successive impulses have derived and validated with simulated and experimental results. The relationships between amplitudes of frequencies for impulse train, delayed impulse train and combination of two impulse trains have established. Frequency spectra for single and two defects on either race of deep groove ball bearings compared. No additional frequencies due to time delay between successive impulses observed in case of multiple defects. The frequency spectra do not provide any information about number of defects; however, this information found in time domain analysis. (patel, 2014)

In 2015, a method presented for calculating and analyzing the quasi-static load distribution and varying stiffness of a radial loaded double row bearing with a raceway defect of varying depth, length, and surface roughness. The metal applied to ball bearings on gearbox and fan test rigs seeded with line or extended outer raceway defects. When balls pass through the defect and lose all or part of their load carrying capacity, the load redistributed between the loaded balls. This includes balls positioned outside the defect such that good raceway sections subjected to increased loading when a defect is present. The defective bearing stiffness varies periodically at the ball spacing, and only differs from the good bearing case when balls positioned in the defect. In this instance, the stiffness decreases in the loaded direction and increases in the unloaded direction. For an extended spall, which always has one or more balls positioned in the defect, this results in an average stiffness over the ball spacing period that is lower in the loaded direction in comparison to both the line spall and good bearing cases. The variation in bearing stiffness due to the defect produces parametric excitations of the bearing assembly. The qualitative character of the vibration response correlates to the character of the stiffness variations. Rapid stiffness changes at a defect exit produce impulses. Slower stiffness variations due to large wavelength waviness features in an extended spall produce low frequency excitation, which results in defect components in the velocity spectra. The contact forces fluctuate around the quasi-static loads on the balls, with rapid stiffness changes producing high magnitude impulsive force fluctuations. Furthermore, it shown that analyzing the properties of the dynamic model linearized at the quasi-static solutions provides greater insight into the time-frequency characteristics of the vibration response. This demonstrated by relating the low frequency event that occurs when a ball enters a line spall to the dynamic properties of the bearing assembly. (dick, 2015)

Chapter Three

Methodology

3.1 Preface

The electronic system is designed to control alarming heat, speed, and vibration in a bearing implemented and accomplished through simulation to early detection of bearing defects .It used in machine and devices that work by single-row radial ball bearing where the required data is set at the desired temperature, vibration, and speed. The required sensors are connected together with the microcontroller for processing the signal ,which in turn will give an appropriate or high amount of the prescribed limit through the use of specific code that meets the conditions. The signal is taken from the movement of mechanical part by the sensors and it is processed and displayed on the screen.

3.2 Block Diagram

The bellow Block Diagram shows the main Bearing system components, which is wholly controlled via ATmega16 Microcontroller.

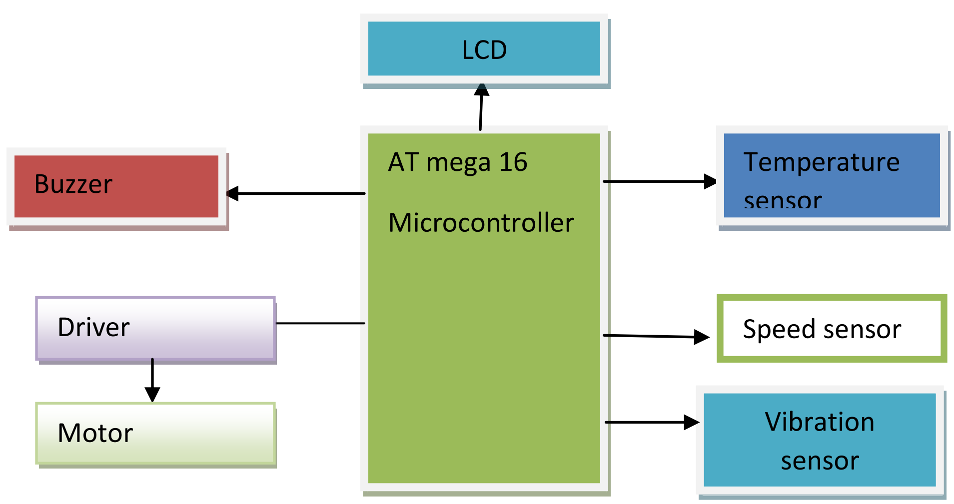


Figure 3-1 block diagram of simulation in bearing system

3.3 Simulation

The diagram below shows the electronic circuit for protecting bearing system simulated through alarming in Proteus software which contains microcontroller, LCD, speed sensor, temperature sensor,ULN2003,Vibration sensor, Buzzer, motor, Relay and 555 Timer . After selecting all the components for simulation and linking them in the appropriate manner; and the selection of the code that runs the simulation, the results are read on screen and are automatically matched ,whether they are suitable for operation conditions or not. If they are suitable the system works without stopping, and in case they are in the dangerous limits the system is shut down.

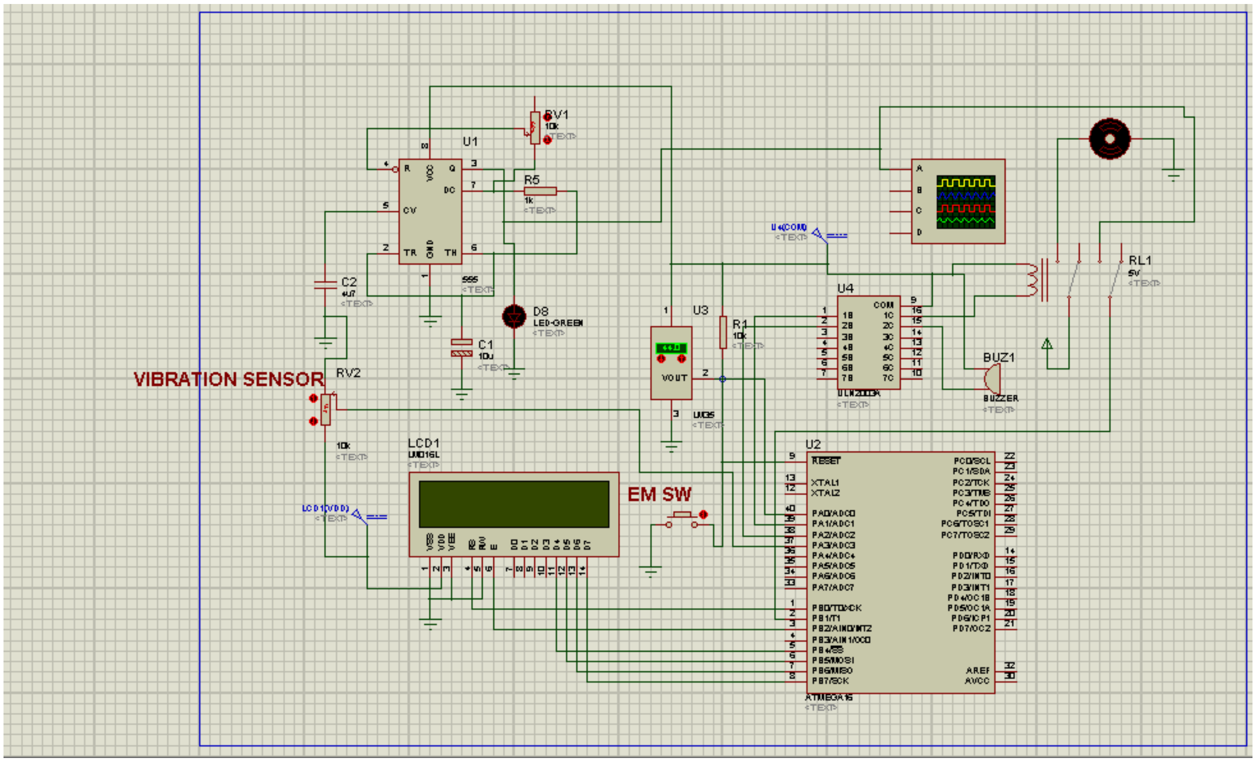


Figure 3-2 Simulation Circuit

3.3.1Software Implementation

The software tools used in this research work to simulate and implement a driver with atmega16 series microcontroller for speed, vibration and temperature control of a DC motor and Proteus Professional.

3-4 Single-Row Radial Deep Groove Ball Bearing

Single row deep groove ball bearings are particularly versatile. They are simple in design, non -separable, suitable for high and even very high speeds and are robust in operation, requiring little maintenance. Deep raceway grooves and the close conformity between the raceway grooves and the balls enable deep groove ball bearings to accommodate axial loads in both directions, in addition to radial loads, even at high speeds. Single row deep groove ball bearings are the most widely used bearing type. Consequently, they are available from SKF in many executions and it determines the range of temperature from -30^{o} to 110^{o} C

Table 2-3 specfication of single-row

Bore mm d	OD mm D	Width mm W	Bearing Number	Basic Load Rating Pounds		Speed Rating		Weight (lb)
				Dynamic	Static	Grease RPM	Oil RPM	
10	35	11	**6300**	1820	780	17000	26000	0.11
12	37	12	**6301**	2180	950	16000	24000	0.13
15	42	13	**6302**	2570	1230	13000	20000	0.18
17	47	14	**6303**	3060	1470	11000	18000	0.25
20	52	15	**6304**	3580	1780	10000	17000	0.32
25	62	17	**6305**	4640	2520	9500	13000	0.52
30	72	19	**6306**	6000	3370	9000	12000	0.80
35	80	21	**6307**	7500	4300	8500	10000	1.00
40	90	23	**6308**	9100	5400	7800	9200	1.40
45	100	25	**6309**	11900	7200	6700	8000	1.80
50	110	27	**6310**	13900	8600	6400	7500	2.40
55	120	29	**6311**	16100	10100	5800	6800	3.02

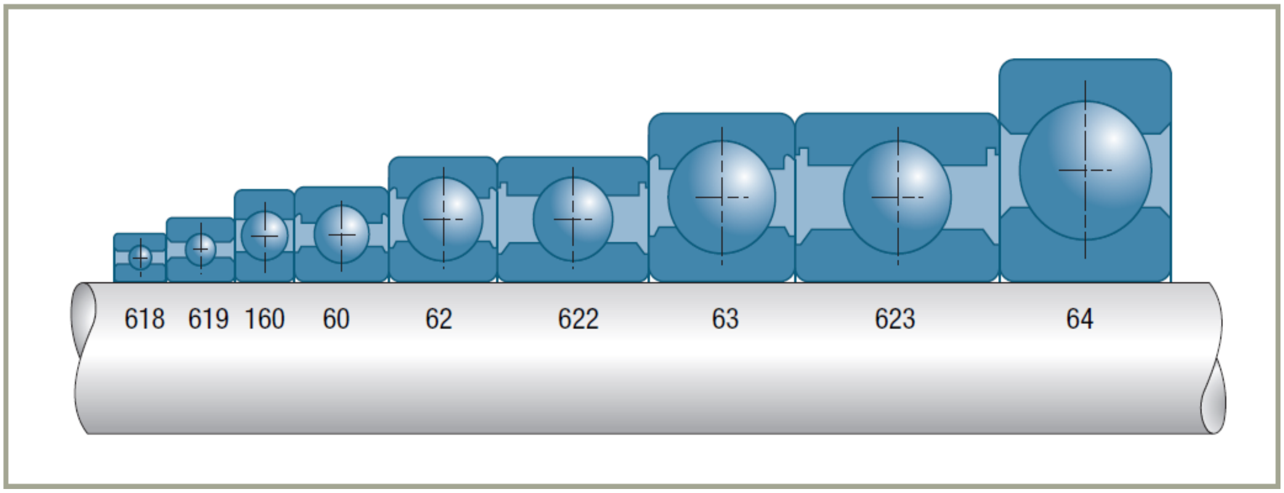


Figure 3-3 Series Single-row Radial Groove ball bearing

Chapter Four

Results and Discussion

4- Preface

In this chapter, the final electronic system is presented and the obtained results from the simulation were discussed.

4-1 Electronic System Configuration

The electronic system components selected to set on for the Buzzer when the temperature, speed, or vibration exceed the limits determined by the manufacturer or the operator of the machine. The electronic system is composed of Atmega16, ULN2003, RELAY, LM 35, 555T, BUZZER, LCD16*2 and DC MOTOR. All these components were selected because they are best suited to give us the desired results and achieve the research objectives.

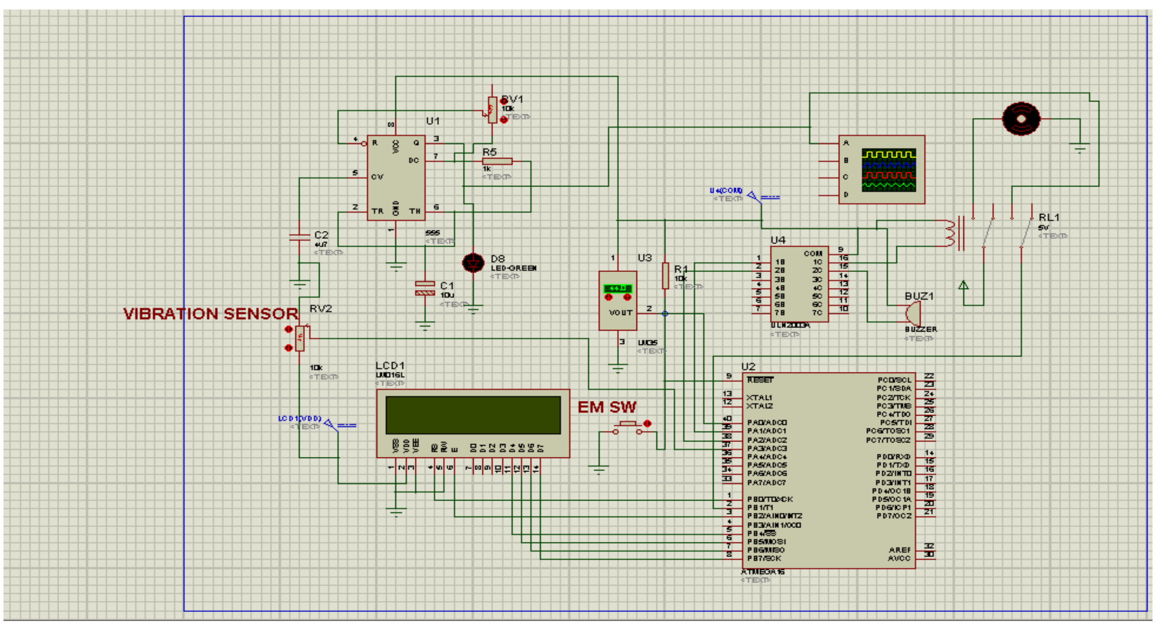


Figure 4-1 Describtion of the System

The components of the system in Figure (4-1)

At the operation of the electronic system the LM35 reads the temperature from the Motor after converting the signal from analog to digital by atmega16, the range of temperature is 0 to 45. After that the speed of the Motor is measured by 555T is similar to IR sensor which contains a transmitter and receiver and it gives the signal as pulses, the maximum speed 3000 rpm. The vibration should be read in LCD by using driver ULN2003 between micro and motor to enlarge current and ban opposite current. The buzzer works on if the temperature, vibration, or speed reach the maximum limit and the motor stop automatically or the emergency switch is used to stop the system manually.

4-2 Discussion

The Figures below show Proteous7.7 in which the electronic system is simulated. The results display the main system status according to the speed, temperature, and vibration of the bearing system. If temperature arises above than the normal limit then this will cause the Buzzer to operate on and the microcontroller will turn of the system until the temperature is decreased below the normal (110 degrees).

In addition, if speed rises above the normal, which will be due to high speed the Buzzer, will be On state and the microcontroller will turn of the system until the speed is below the normal (3000 degree).

In addition, if vibration rises above the normal, which will be due to high vibration ,the Buzzer will be on state and the microcontroller will turn of the system until the vibration is decreased below the normal (334 HZ).

4.3 Simulation Results

The general system is implementing the main results :

Figure 4-2 shows dangerous speed buzzer on stop motor and stop system. In this Figure we see in the screen speed dangerous and buzzer on which means the speed of motor is high than 3000 rpm which is considered as a dangerous level of speed, and hence,the system is stopped.

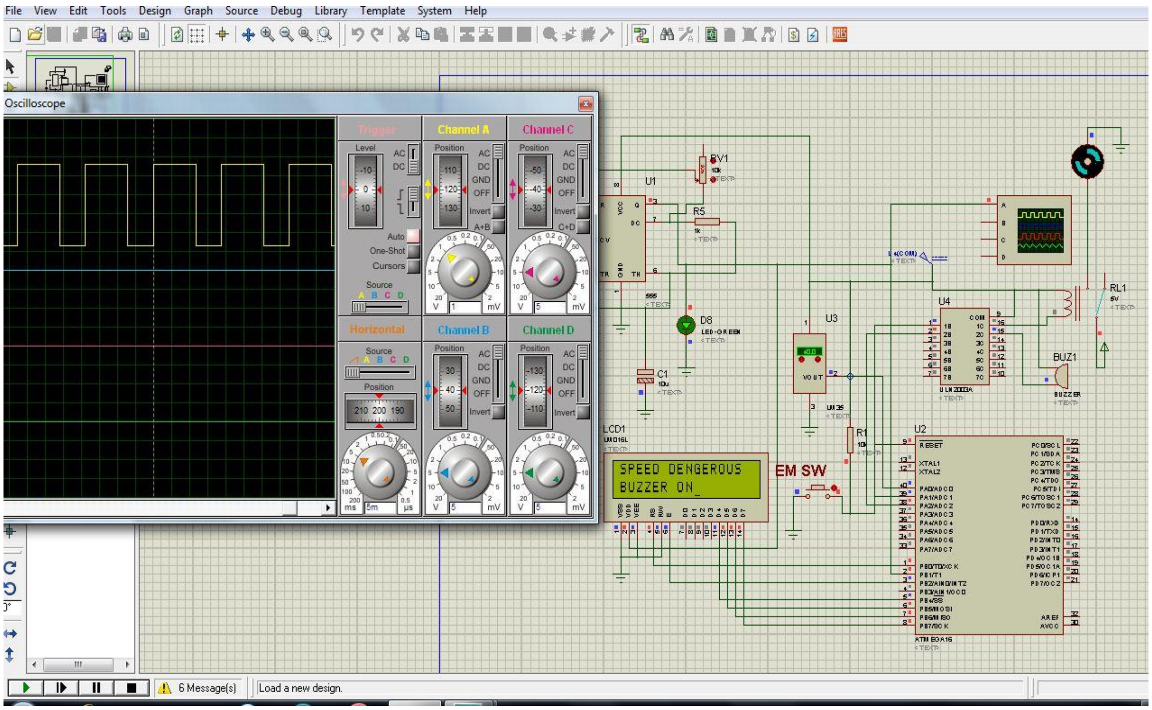


Figure 4-2 Result one

Figure 4-3 shows temperature high buzzer on stop motor and stop system, in this figure we see in the screen Temp High and stop motor, the buzzer on that means the temperature of bearing motor is high than 110 rpm which is considered a dangerous level of temperature, hence the system is stopped.

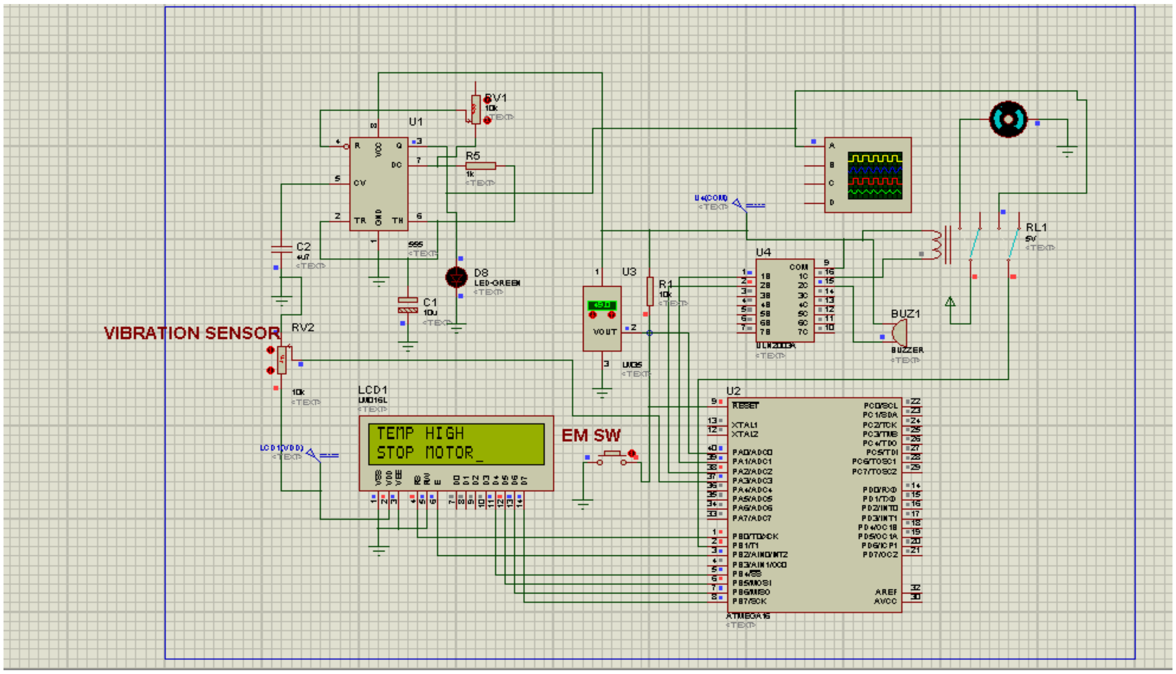


Figure 4-3 Result Two

Figure (4-4) shows temperature, speed, and vibration of system, in this figure all work conditions are written in the screen and all of them are not in a dangerous level which means the system is work normally.

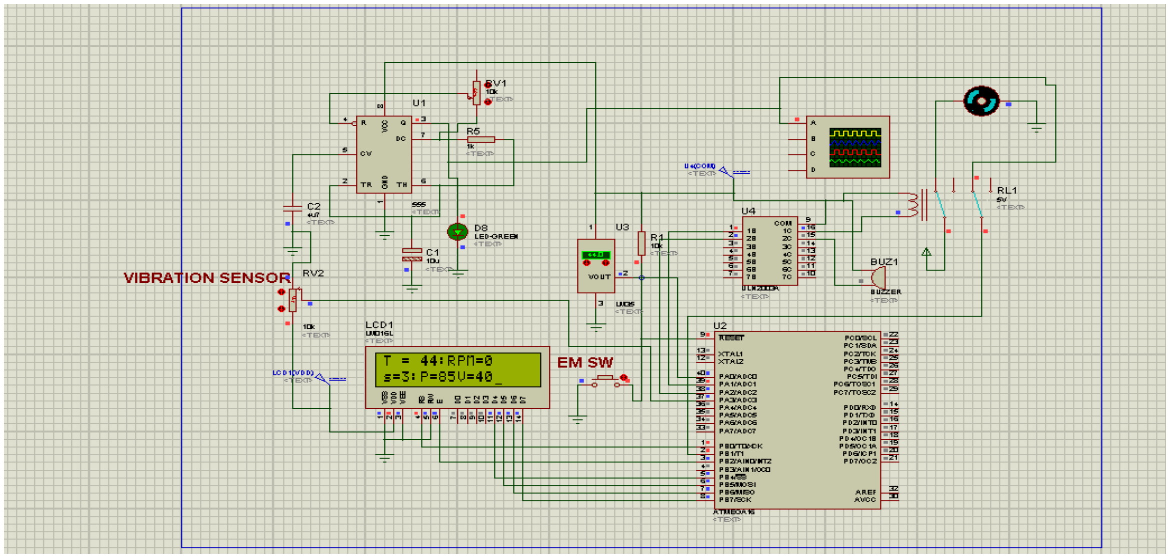


Figure 4-4 Result Three

Figure (4-5) shows vibration dangerous buzzer on stop motor and stop system, in this Figure we see in the screen vibration dangerous and stop motor, the buzzer on that means the vibration of bearing motor is high than 334 HZ which is considered a dangerous level of vibration, hence, the system is stopped.

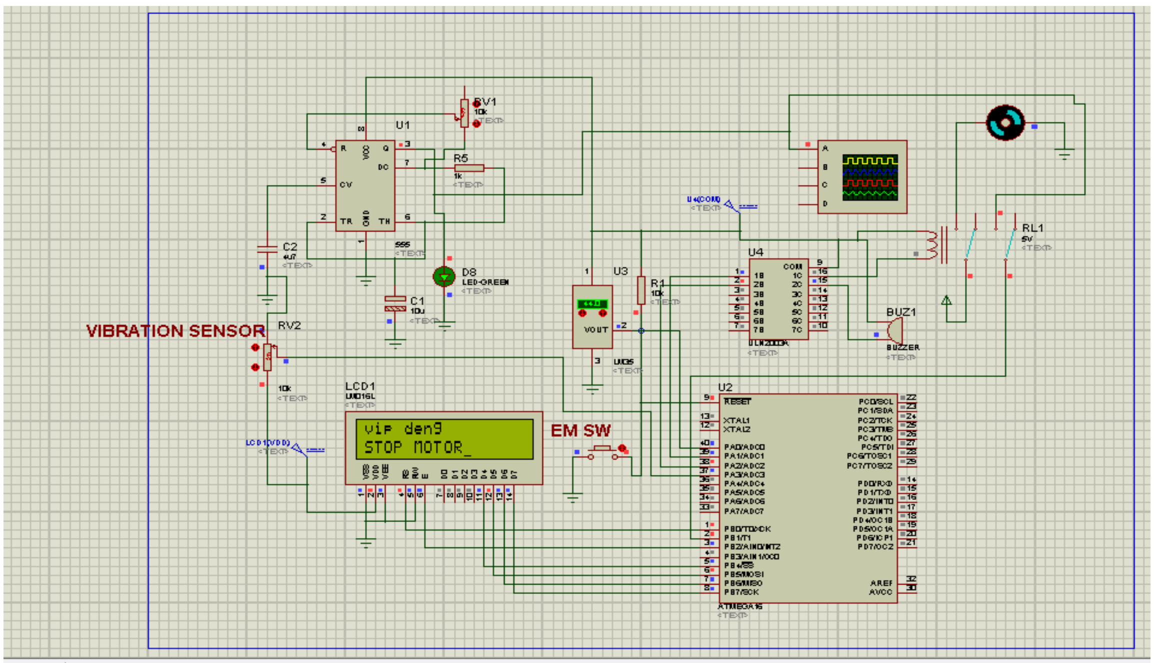


Figure 4-5 Result Four

4.4 Evaluation of research

According to the system performance, the evaluation of the electronic system is conducted which is using microcontroller Atmega16, that is the main controller of the system to control three multiple sensors (speed, vibration and temperature) of the system. For the adjustment of the dynamic change of the Bearing system operation during high speed and multi-temperatures degrees during the over speed conditions. Such modification could adequately adapting the overall system lifetime and decrease maintenance of malfunctioning operation due to high speed, vibration, and temperatures operations conditions.

The validity for many specialties such as mechanics, electrical and electronic might be invested in for the protection of bearing and minimizing the cost of replacement of spare parts. Besides, the achievement of the proposed objectives and association of the design with them and hence the conducting of this research will be so highly justified level to help in the avoidance of dangers that could occur.

Chapter Five

Conclusion and Recommendations

5.1 Conclusion

Based on the conclusion of this research and the drawn results therefrom ,a simulation system was conducted to protect the bearing from the dangers of heat, speed and high vibration in order to avoid the risks that might occur and the research reached a conclusion of the obtainment of a permanent monitor of the operation conditions.

This was carried out through the simulation program, which works to imitate the real process and link all the components mentioned within the research ,such as sensors, motor, relay, microcontroller, driver, LCD and others. To work on the reading of the signal from the motor and converted to the screen after passing by micro to display all quantities that have been measured.

All the results achieved by simulation analyzes the temperature, vibration and speed and sometimes if appropriate, it leaves the system working or in case, the maximum limit of the system is disabled.

5.2 Recommendations

Based on the identification and addressing of the problem, this researcher set forth a recommendation to be used by other researchers, who want to make benefit therefrom in respect of the protection and making further studies on bearing. So that they can achieve additional improvements and adjustments or to add more knowledge towards an establishment of a basis of an integrated project.

In addition, the research can be applied in a practical way on the ground in all devices that contain bearings and correct errors whenever they occur.

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