A PROJECT REPORT ON

VIBRATION SIGNAL ANALYSIS FOR BEARING FAULT DIAGNOSIS USING LABVIEW

A Thesis Submitted In Partial Fulfilment of the Requirements

for the Degree

of

BACHELOR OF TECHNOLOGY

in

INSTRUMENTATION ENGINEERING

by

HRISHIKESH DAS (Roll No. GAU-C-11/L-216)

NAYAN JYOTI BORO (Roll No. GAU-C-11/83)

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Under the supervision of

MR. GANESH ROY
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DEPARTMENT OF INSTRUMENTATION ENGINEERING

केन्द्रीय प्रौद्योगिकी संस्थान कोकराझार

CENTRAL INSTITUTE OF TECHNOLOGY KOKRAJHAR

(A Centrally Funded Institute under Ministry of HRD, Govt. of India)

BODOLAND TERRITORIAL AREAS DISTRICTS:: KOKRAJHAR :: ASSAM :: 783370Website:

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MAY 2015

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DECLARATION

We hereby declare that the project work entitled **'VIBRATION SIGNAL ANALYSIS FOR BEARING FAULT DIAGNOSIS USING LABVIEW'** is an authenticated work carried out by us under the guidance of **Mr Ganesh Roy** for the partial fulfilment of the award of the B.Tech degree in Instrumentation Engineering and this work has not been submitted for similar purpose anywhere else except to Department of IE, Central Institute of Technology, Kokrajhar.

Date:

Place: Kokrajhar

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DEPARTMENT OF INSTRUMENTATION ENGINEERING

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(An Autonomous Institute under MHRD)

Kokrajhar – 783370, BTAD, Assam, India

CERTIFICATE OF APPROVAL

This is to certify that the work embodied in this project entitled **"VIBRATION SIGNAL ANALYSIS FOR BEARING FAULT DIAGNOSIS USING LABVIEW"** submitted by **Hrishikesh Das**(Gau-C-11/L-216), **Nayan Jyoti Boro**(Gau-C-11/83) and **Abhi Ghosh**(Gau-C-11/L-217) to the Department of Instrumentation Engineering, is carried out under our direct supervisions and guidance.

The project work has been prepared as per the regulations of Central Institute of Technology, Kokrajhar and I strongly recommend that this project work be accepted in partial fulfilment of the requirement for the degree of B.Tech.

Supervisor

Mr. Ganesh Roy

Asst. Professor Dept. of Instrumentation Engineering

DEPARTMENT OF INSTRUMENTATION ENGINEERING

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CERTIFICATE BY THE BOARD OF EXAMINERS

This is to certify that the project work entitled **"VIBRATION SIGNAL ANALYSIS FOR BEARING FAULT DIAGNOSIS USING LABVIEW"** submitted by **Hrishikesh Das**(Gau-C-11/L-216), **Nayan Jyoti Boro**(Gau-C-11/83) and **Abhi Ghosh** (Gau-C-11/L-217) to the Department of Instrumentation Engineering of Central Institute of Technology, Kokrajhar has been examined and evaluated.

The project work has been prepared as per the regulations of Central Institute of Technology and qualifies to be accepted in partial fulfilment of the requirement for the degree of B. Tech.

Project coordinator

Board of Examiners

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This is to certify that the following students of 8th semester B.Tech course, **Hrishikesh Das** (Gau-C-11/L-216), **Nayan Jyoti Boro** (Gau-C-11/83) and **Abhi Ghosh** (Gau-C-11/L-217) of Instrumentation Engineering have submitted their project report on" **VIBRATION SIGNAL ANALYSIS FOR BEARING FAULT DIAGNOSIS USING LABVIEW**" to the department in partial fulfilment of the requirement for the degree of B. Tech in Instrumentation Engineering.

Date: 18.05.15

Place: Kokrajhar

Jeet Dutta

Mr. Jeet Dutta

Assistant Professor and HOD (i/c)

Department of Instrumentation Engineering

Central Institute of Technology, Kokrajhar

Abstract

Rotating machine plays a vital role in the plant. Bearing are one of the critical components in the rotating machinery. Various maintenance technique such as breakdown maintenance, preventive maintenance and predictive maintenance are performed for maintenance of a machine. Vibration analysis of bearing is the predictive maintenance technique used for fault diagnosis of machine bearing. Fault in the bearing causes change in vibration in the bearing. The main objective of this project is to detect the bearing faults (outer race fault) in a mechanical system using the vibration signal from the bearing. In the project the vibration signal is analysed in the LabVIEW software which is sensed by a piezoelectric transducer. For avoiding the difficulties in time domain analysis, we have performed frequency domain analysis. FFT is employed for a first comparison between healthy and defective bearing.

Acknowledgement

It is high privilege for us to express our deep sense of gratitude to all those members specially **Niron Daimary**, **Kalyanjee Barman** and **Santanu Swargiary** who helped us in the completion of the project, especially **Mr. Ganesh Roy** sir who was always there at our need.

Date:

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LIST OF ABBREVIATIONS

DAQ: Data Acquisition.

DAS: Data Acquisition System.

PC: Personal Computer.

VI: Virtual Instrumentation.

LabVIEW: Laboratory virtual instrument engineering workbench.

FFT: Fast Fourier Transforms.

VFSS: Vibration Faults Simulation System.

PET: Piezoelectric Transducer.

I/O: Input Output.

ADC: Analog to Digital Converter.

IIR: Infinite Impulse Response.

CHAPTER 1

1 Introduction

Electrical machine plays a vital role in the plant. Vibration signal analysis has an important tool in area of fault diagnosis. Vibration based diagnosis has always been considered reliable and easy to use. Vibration occurs in machine in different plants. The risk of machine faults can remarkably create serious danger to day to day life and productive activities of the people. Vibration can produce the noise as well as energy, which are very much harmful to human health. It also can affect the equipment life and operation stability of machine. It causes great losses to the plant. So maintenance is a very important factor for a machine, which is essential. The effect of vibration can be eliminated or reduced from the machine by using vibration signal monitoring and analysis. Vibration is considered as a good indicator of machine monitoring system. The monitoring and analysis of vibration signals is the one of the area of application of LabVIEW. The monitoring and analysis of vibration signal are concern for implementing the predictive maintenance and fault detection. Various information about the states change of vibration signal and faults feature of the machine are displayed in the vibration signal. So the measurement and analysis of vibration signal are necessary for reducing the effect of vibration. Sufficient training is required to familiarize with different parameter. So that, given analysis method can be effectively applied for eliminating the effect of vibration. The performance of the rotating machine can also be determined by measurement and analysis of vibration signal. Vibration fault simulation system is developed to achieve a better understanding about the faults of machine. A LabVIEW application based data acquisition system is used to analyze this fault signal.

1.1 Introduction to Labview

LabVIEW is a fully featured graphical programming language produced by National Instruments. LabVIEW is a programming language that uses icons instead of line of text to create applications. LabVIEW is text based programming language; the graphical instructions determine program instruction. This software is used for a wide variety of applications and industries. Thus LabVIEW is a much loved tool of the scientist and engineer who can often visualize data flow rather than how a text based conventional programming language must be built to achieve a task.

LabVIEW programs are called virtual instruments, or VIs, because their operation and appearance imitate the physical instruments, such as millimeters, oscilloscopes etc. LabVIEW contains a comprehensive set of tools for displaying, acquiring, analyzing and storing data, and tools help us troubleshoot our programming code. LabVIEW VIs contain three components- the front panel, the block diagram, connector panes and the icon. After we build the user interface, we can add code using VIs and structures to control front panel. The block diagram contains this code and the block diagram resembles the flowchart. To communicate with hardware such as data acquisition, and motion control devices, and, PXI, GPIBVXI, RS- 484, and RS-232 devices we can use LabVIEW software. LabVIEW Web server and software standards such as TCP/IP networking using LabVIEW, we can create, test and measurement, instrument control, data logging, data acquisition, measurement analysis and apply generation applications. We also stand-alone executable and shared libraries, like DLLs, as because LabVIEW is a true 32-bit compiler software.

1.2 Literature Study

1. Sunita Mohanta, Specialization: Electronics and Instrumentation Engineering in the department of Electronics and Communication Engineering at University College of Engineering National Institute of Technology Rourkela, Odisha.

She has published a paper " A LabVIEW based data acquisition system for monitoring and analysis of vibration signal" issued from international Journal of Institute of Electrical and Electronics Engineering(IEEE) Xplore in the year of 2011-2013.

According to her Thesis monitoring and analysis of vibration is a predictive maintenance technique by which the faults can be detected in the machines. So the main purpose of this work is to find out the error extent and error region of the vibration signal and taking the necessary control action to stop the machine. The system consist of a motor, piezoelectric transducer, DAQ, voltage controlled current source and computer.

2. Heta S. Shah, Pujaben N. Patel, Shashank P. Shah, and Manish T. Thakker at the University college of Dharmsinh Desai University, Nadiad.

They design a project" 8 Channel Vibration Monitoring and Analyzing System Using LabVIEW" at Nirma University International Conference on Engineering in 2013.

According to their project vibration monitoring signal system has been investigated in details. The construction of circuit, design of vibration monitoring system and experimental investigation has been reported. This system requires minimum hardware. A user friendly interface based on LabVIEW is used for monitoring vibration.

3. Sukhjeet Sing, Amit Kumar, Navin Kumar at the school Mechacinical, Materials and Energy Engineering, Indian Institute of Technology Ropar, Nangal Road, Rupnagar, Panjab, India.

They had published a paper "Motor Current Signature Analysis for Bearing Fault Detection in Mechanical Systems" in 3rd International Conference on Materials Processing and Characterization 2014.

According to their paper Bearing are one of the critical components in rotating Machinery. The need of an easy and effective fault diagnosis technique has led to the increasing use of motor current signature analysis. Vibration based diagnostics has always been considered reliable and easy to use.

CHAPTER 2

2 Components Used (Software & Hardware)

Vibration monitoring and Analysis system consists of following components: sensor system, vibration signal acquisition, vibration signal analysis, vibration signal processing, vibration signal display and recording. The structure of the vibration monitoring system for fault diagnosis is shown in Fig.1 In vibration monitoring system, different components like piezoelectric transducer, data acquisition card, and computer are required. For controlling of machine, motor control unit is required. In this system, data acquisition is considered as hardware of the system. The LabVIEW software is installed in the computer for processing of the vibration signal.

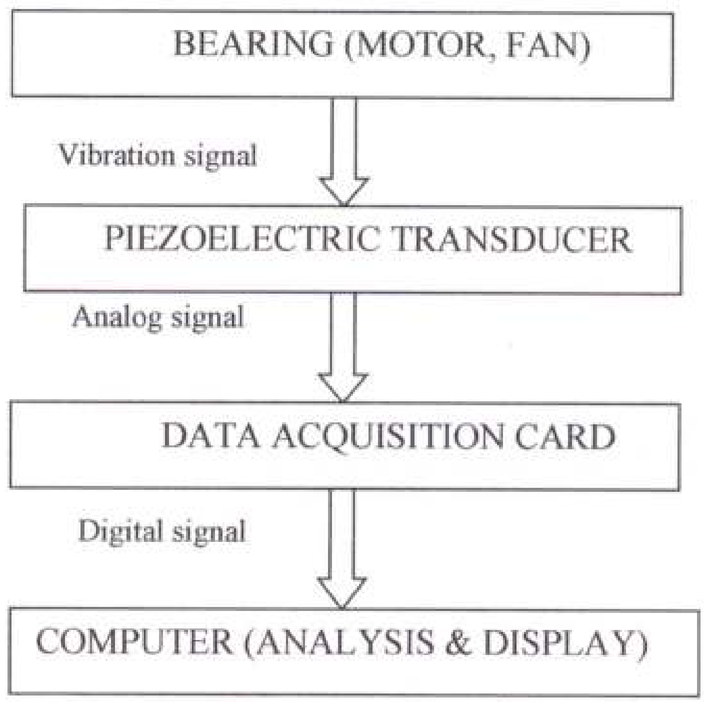


Figure 1: Component of Vibration Monitoring System

2.1 Motor (Split Phase Ac Induction Motor)

Motor is the one of the important equipment to convert electrical energy to mechanical energy in the modern production, and it plays an important role in the recent industrial plants. Typical components of a machine like shafts, bearing, gears, rotors, drive belts are monitored. Common problem associated with the machine components are Imbalance, misalignment, ball bearing, looseness, bent shaft, journal bearing, gear problem, impeller blade problem, motor problem etc. In this work, Virtual instrumentation and vibration analysis are applied to motor to monitor and detect various failures. When a machine runs, it creates vibration .this vibration give a vibration signal which is sensed by an acceleration transducer. Acceleration transducer mounted on the machine. Specifications of the analyzed motor are given below.

i. Type = Split phase (Asynchronous)
ii. Frequency = 50/60 Hz
iii. Speed = 2800 rpm
iv. Output power = 15 watt
v. Input voltage = 110/220-230 V

Figure 2: Split Phase Ac Induction Motor.

2.2 Bearing

A bearing is a machine element that constrains relative motion to only the desired motion, and reduces friction between moving parts. The design of the bearing may, for example, provide for free linear movement of the moving part or for free rotation around a fixed axis; or, it may prevent a motion by controlling the vectors of normal forces that bear on the moving parts. Many bearings also facilitate the desired motion as much as possible, such as 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. The tested bearing specifications are given in the next page.

I. Number of balls (N_b) = 8
II. Pitch diameter (D) = 25 mm
III. Contact angel of bearing = 0°
IV. Ball Diameter = 6 mm
V. Shaft Speed = 2800 rpm

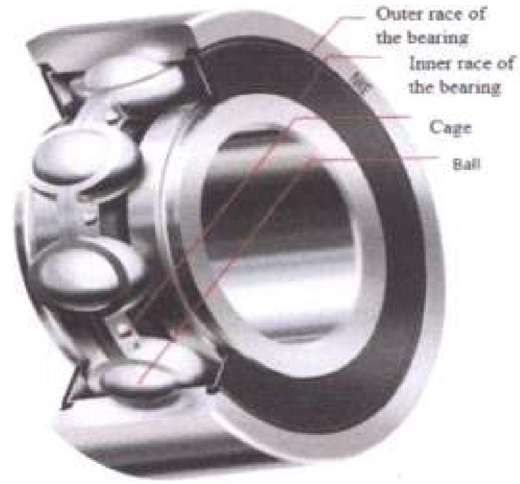


Figure 3: Bearing

2.3 Piezoelectric Transducer

Mostly Piezoelectric transducer is widely used transducer for vibration monitoring and analysis system. Piezoelectric transducer contains piezoelectric crystal element. It is preloaded by a mass of certain value. The whole assembly is enclosed in a strong protective covering. An electrical output (low voltage or charge) is generated by the piezoelectric crystal, when the crystal is physically stressed by the vibration of machine. The crystal is stressed due to the variable inertial force of the mass and produces an electrical signal proportional to acceleration of that mass. For acceleration measurement, this small acceleration signal can be amplified to a standard unit. This acceleration signal is converted (electronically integrated) into a velocity or displacement signal within the sensor. This is commonly considered as the ICP (Integrated Circuit Piezoelectric) type transducer or sensor. It has an extensive frequency range. It can be performed well in accurate phase measurements and also in wider temperature range. It resists damage due to sever vibrations and shocks. Now a days internal amplifier is included in most of the PE transducer. It has some advantages, these are; it has provision for providing relative immunity to the effects of poor cable insulation and high output to weight ratio.

Specifications of the PE transducer are given in the next page.

I. Flat frequency range (HZ):20-1500HZ or 20-10000Hz.

II. Temperature limitation (°C): -50to +120°C.

III. Sensitivity range (mV/g):100mV/g.

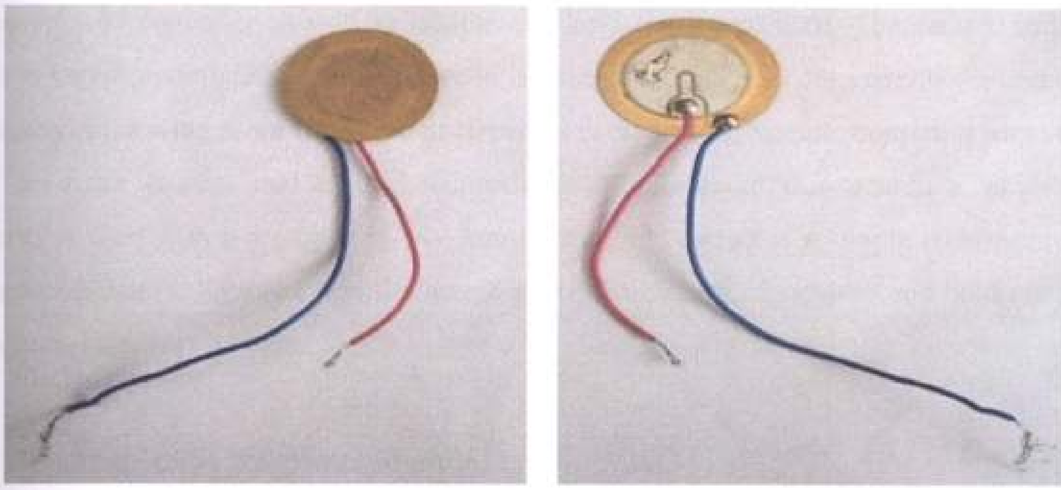


Figure 4: Front View and Back View Of Piezoelectric Transducer.

2.4 Data Acquisition

A data acquisition system is defined as the process in which physical signals are transformed into electrical signals which are then measured and converted to digital signal for processing, collection, and storage by a computer. It is the hard ware part of virtual instrumentation. The analog signal from the charge amplifier goes to data acquisition card. A DAQ system consists of various components. These are incorporated to following points:

- DAQ system senses the physical variable.
- Conditioning of electrical signal to make it understandable by an A/D converter board.
- It converts the electrical signals into digital signals which are acceptable by computer.
- Process, analyse, and display the acquired digital data with the help of LabVIEW software.

Data acquisition system can be broadly classified as two types -

- Single channel data acquisition system.
- Multichannel data acquisition system.

2.5 Multichannel Data Acquisition System

In multi-channel data acquisition system, multiple parameters or different version of data for the same parameter can be acquired in a single time by which we can increase the efficiency as well as throughput to a higher extent. In this data acquisition system multiple number of A/D converter as well as sample and hold circuit are used. The sample and hold circuit is very economical and trouble-free in construction. But A/D converter components are very costly and having more complicated circuit. It is difficult to execute numerous numbers of ADC converter circuits due to high expenditure. Therefore in this system a single A/D converter is used with a multiplexer. As Sample and hold circuit is a simple architecture and cheap configuration, So that we will connect multiple numbers of samples and hold circuit in each channel.

2.6 Data Acquisition Hardware Module

The data acquisition hardware module is sandwiched between signal conditioning element and the laptop or computer. The most important function of this device is that it digitizes the incoming analog signal to measurable digital signal. Following operations are performed by the DAQ system hardware.

- Analog input.
- Analog output.
- Timing input /output (I/O).
- Digital input/output (I/O).
- Counter.
- Multifunction.

The basic components of DAQ hard ware module are given below:

- ✓ Multiplexer
- ✓ Sample and Hold circuit
- ✓ Signal conditioning circuit
- ✓ ADC(Analog to Digital converter)
- ✓ DAC(Digital to Analog converter)
- ✓ Driver and application software

A. Multiplexer

Multiplexer is a switching device in which only one channel from several input channels are connected to the instrumentation amplifier circuit at a time. When the signals are acquired from several input channels, the multiplexer rotates through the channels by connecting them one by one to the amplifier. The order of the multiplexer is controlled by LabVIEW software.

B. Sample and Hold Circuit

In many systems, sample and hold circuit(S/H) is used on the input to the ADC circuit for freezing the signal while the ADC circuit digitizes the input signal. The errors are prevented due to changes in the signal throughout the digitization process. In some implementations, as soon as the signals have been grabbed by the sample and hold circuit the multiplexer is switched to the next channel in a sequence. The digitization process is allowed to proceed in corresponding with the settling time of the amplifier and multiplexer. This process is enhancing throughput. Sample and hold circuits are also used to capture transient signals.

C. Signal Conditioning Circuit

The signals are generated by transducers are very difficult to measure directly with a DAQ device hard ware. When we are dealing with noisy environments, high voltages, and extreme high and low signals, signal conditioning is very essential for an efficient data acquisition system. It will increase the accuracy of the system. The design procedures of signal conditioning circuit are different for different application.

D. Filtering

A filter is used to remove the unwanted signals from the acquired signal which is to be measured. If the noise signals are not removed, they will imprecisely appear in the acquired signals within the input bandwidth of the measuring vibrator device. Filtering can be implemented in both in software and hard ware. In most of the cases noise is created by overhead lights and ac power like computer power supply. Noise is occurred at around 60 Hz. A low pass filter can be used to remove noise having a cut-off frequency less than 60 Hz.

E. ADC (Analog to Digital Converter)

An analog to digital converter (ADC) converts the analog signal to into digital signal which is then sent to the computer for processing analyzing the signal. The analog input circuitry merges with the A/D converter to acquire analog signal, so that the shape, level, frequency of the signal can be analyzed and measured. There are three types of A/D converter are there like flash converter, dual ramp, successive approximation. Generally in industrial application, successive approximation is used as an effective DAC.

F. DAC (Digital to Analog Converter)

Digital to analog converter converts the digital signal to analog signal. Digital numbers are acquired from the computer through an I/O interface circuitry. The output analog signal is acquired through an I/O connector. A DAC is essential for generating DC signals with specific level, frequencies and shapes.

G. Driver & Application Software

The entire system is transformed into a single integrated module through DAQ software. As a result a control action can be taken over the DAQ hardware module. The DAQ module will not perfectly work without applying any software to drive or control the hardware module. Driver software is software which is easily communicated with the data acquisition hardware module. The intermediate layer is formed by the driver software between hard ware module and application software. It is also a configuration-based program having preset functionality. Application software includes analysis and presentation capability to driver. Using application software, analysis and presentation abilities are added to the driver software. Generally there are three interfaces of DAQ system for sending and receiving the signals.

- I/O connector.
- Computer I/O interface circuitry & Real-Time System Integration (RTSI) Bus.

There are various factors, which are affecting the performance of data acquisition system. These are signal conditioning requirement, resolution, range, gain, sampling frequency and connection to ground terminal. The analog to digital conversion is followed by various steps like sampling, quantization and encoding. Sampling is a process in which the data is acquired by an ADC. An analog signal is sampled at discrete time periods. Sampling frequency is defined as the rate by which the signal is sampled. The sampling process generates the signal values as a function of time. The sampling frequency determines the superiority of the analog signal conversion process. Higher sampling frequency realizes better conversion of the analog signal to digital signal. The sampling frequency must be always satisfied Nyquist Theorem.

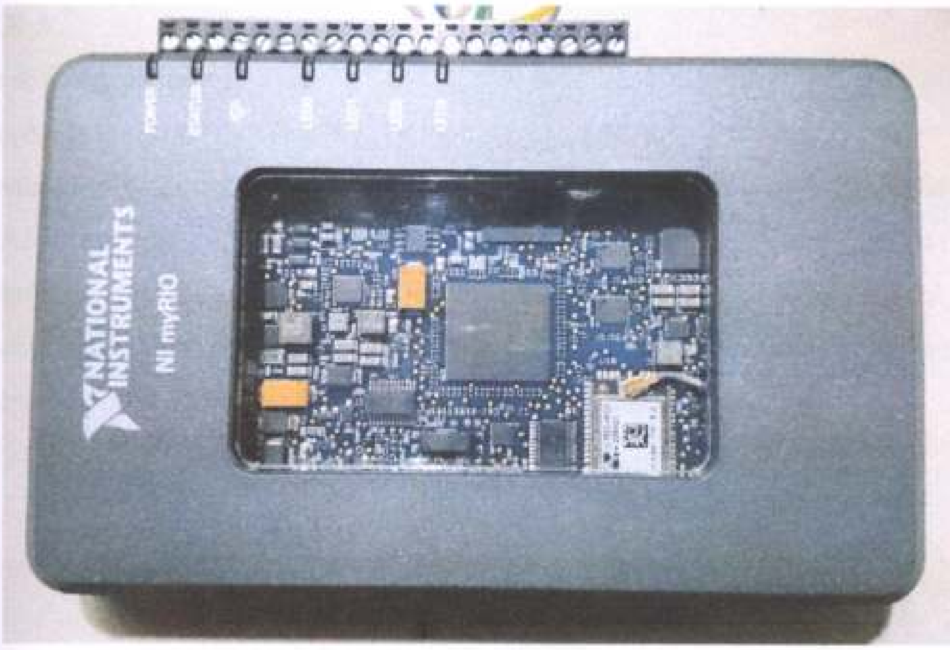


Figure 5: Data Acquisition Card NI myRIO 1900

2.7 DAQ Software

In the vibration monitoring system, computer acts as a software of virtual instrumentation. From the data acquisition card the digital signal is going to the computer. Here the analysis of the vibration signal is done by LabVIEW software. The signal processing is done in terms of time domain and frequency domain .The failure analysis of the vibration signal is done here. And at last the actual result will be displayed by the computer. For which we can take the control action in the machine. All the processes like signal processing, analysis, storage, display are done by using the LabVIEW software. There is other different programmable software are available for signal analysis and monitoring, such as

- C, C++, Visual C++
- Matlab

But all the above software has many disadvantages, such as they occupy large memory, difficult to write an error less lengthy code. These are very complex and time consuming. To avoid the above disadvantages LabVIEW software is used as graphical programming language. Here icons are used to create application instead of line of text. For this reason LabVIEW is very popular. It has verity of application such as data acquisition, signal processing, signal analysis, signal monitoring and control.

CHAPTER 3

3 Design & Programming

3.1 Methodology

In vibration analysis, vibration transducer is mounted with machine, which is shown in Figure 7. Accelerometer transducer is used as a vibration transducer. When vibration occurs in machine three parameters are changed. The three parameters such as displacement, velocity, and acceleration are representing the detected motion by vibration monitoring and analysis. These parameters can be measured by accelerometer transducer.

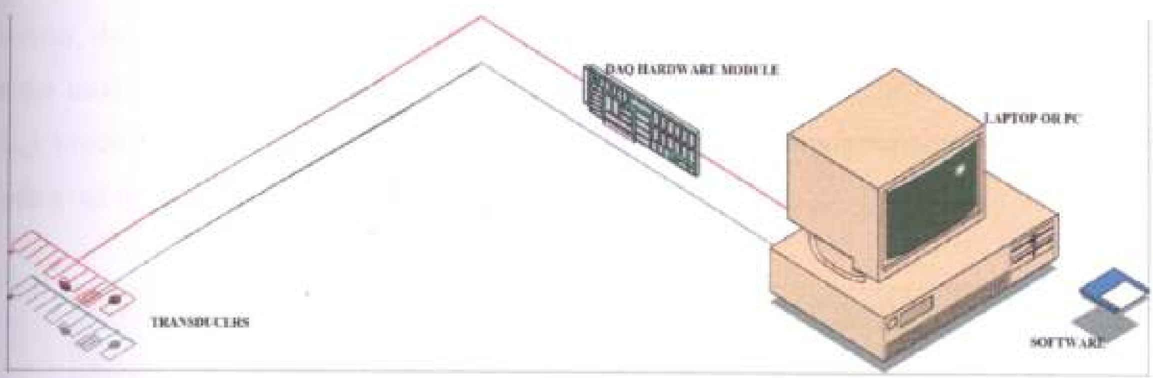


Figure 6: A PC Based Data Acquisition System for Vibration Monitoring

Acceleration transducer is used hare as a vibration transducer. Here The X- axis accelerometer and y-axis accelerometer are found in the graph. The derivative of acceleration of the vibration signal is done easily which is shown in the next section. So that it is easy to find out the error or fault. It has produced the analog signal in terms of time domain. Now it is passed to the signal conditioning element. Data acquisition card converts the analog signal to digital signal through ADC which is implanted in the data acquisition card. The digital signal from the DAQ card is then passed to computer. It performs the analysis of the vibration signal by LabVIEW software and display the result. In vibration signal monitoring system, the hard ware module of myRIO 1900 is used as a data acquisition card. This hardware module has the maximum voltage of +10v. The maximum voltage range is -10v to+10v.The ADC resolution of this module is 16 bit.

3.2 Setup and Procedure

The experiment setup consist of a split phase asynchronous 15 kW induction motor coupled with mild steel shaft of 15 mm diameter mounted on one deep groove ball bearing fixed in one plummer block. The experimental setup is shown in fig.7. A voltage regulator has been attached with the motor in order to adjust the motor speed which can be varied 0 to 2800 rpm. A piezoelectric transducer is coupled to the bearing with the help of the black tap as shown in the fig.1. The motor bearings are healthy. The faults in the bearings installed in the mechanical system were installed artificially. The ball bearing specification are given in page No. 6. The output from the accelerometer given to the data acquisition system of National Instruments (NI myRIO 1900) attached with a PC with NI LabVIEW software. The rotational speed of the shaft is measured with a tachometer

Two sets of experiment were conducted, first with the healthy and second with the defective bearing installed in the mechanical system. If there is a fault in the inner/outer raceway, the balls will pass over the defect point/area, which produces vibration while rotating on the machine with a fixed frequency. This frequency is known as characteristic frequency (f_{bng}), which is associated with different type of bearing faults. The mathematical calculation for finding out the f_{bng} is given in equation No. 13.

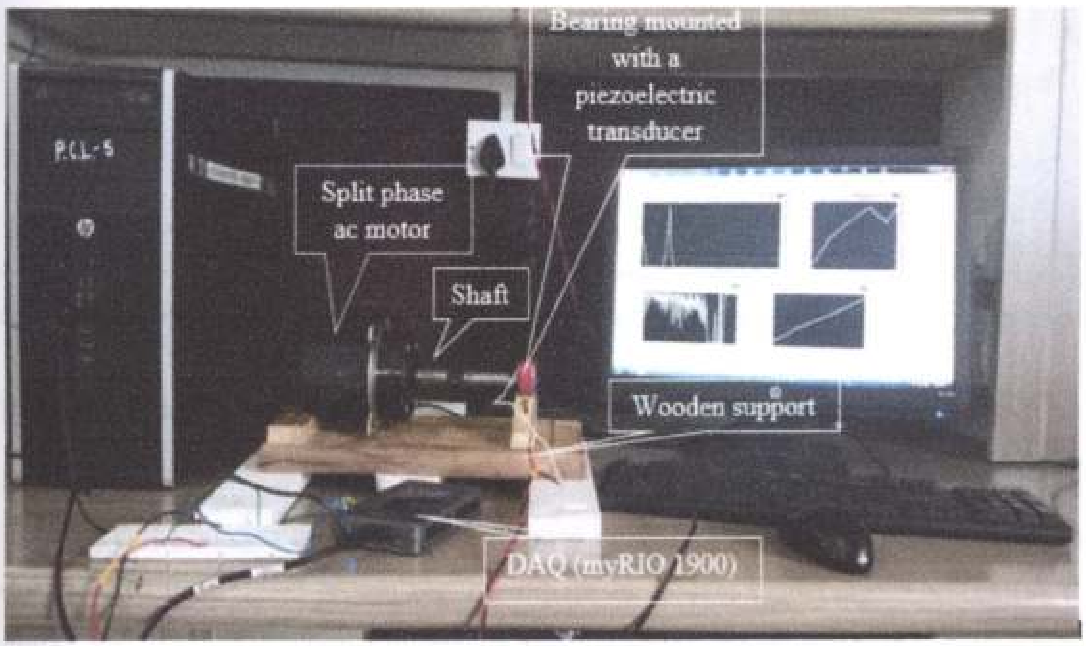


Figure 7: Experimental setup

3.3 Vibration Signal Analysis & Programming

We can analysis and processing of data acquired by the sensor. The input signal is coming from the piezoelectric sensor with a high frequency is processed with a Butterworth band pass filter in LabVIEW program. As a result the vibration signal is recovered. These data is in 3U (acceleration, velocity, displacement). For further analysis data must be converted in

DC RMS and at the same time, the system can analyze the filtered signals in both time domain and frequency domain. Here, Fast Fourier Transformation is applied for identifying the frequency at which the fault came. Which means that it informs us how much is amplitude of each frequency component in the signal.

The block diagram of the simulated system is illustrated in the figure below. The user can have a further analysis by the corresponding parameter configure and icons.

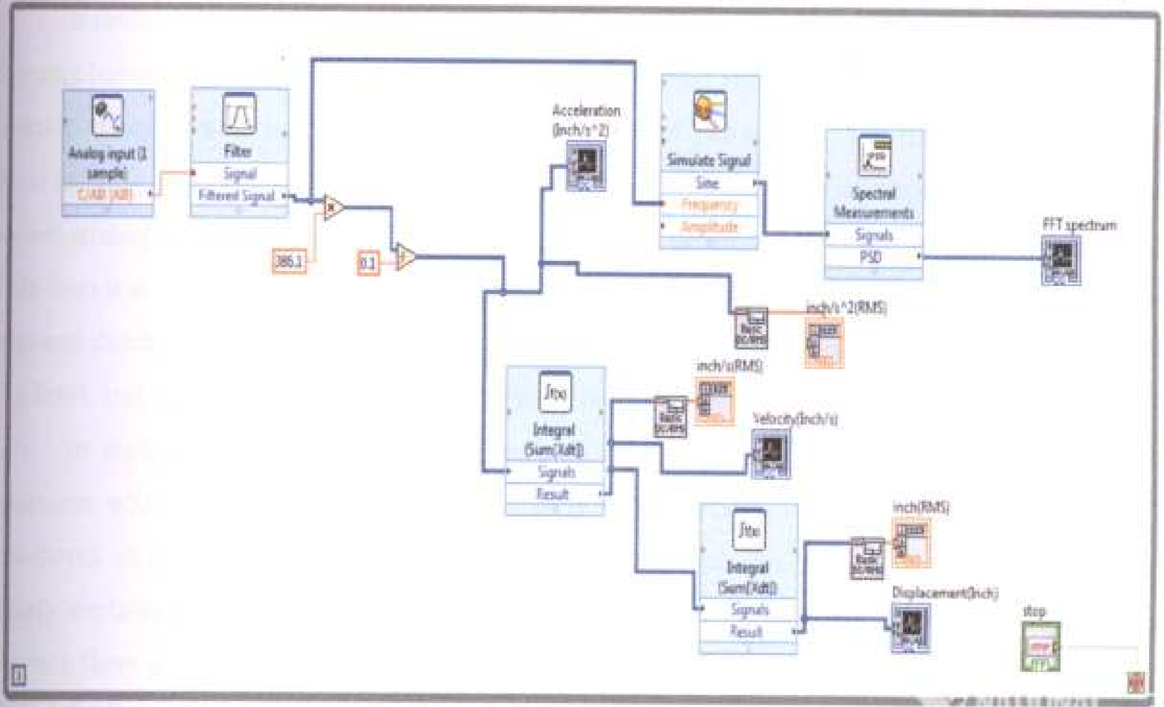


Figure 8: LabVIEW Block Diagram for Vibration Monitoring and Bearing Fault Diagnosis

3.4 Vibration Signal Processing

3.4.1 Digital Filter

Filtering is the process by which the frequency content of a signal is altered. It is one of the most commonly used signal processing techniques. In modem digital signal processing the analog filters are replaced to digital filters by using various signal processing tools. It has applied in many applications that involve flexibility and programmability. Digital filters have the following advantages over their analog equivalent:

i. They are programmable.
ii. They are stable and predictable.
iii. They do not drift with temperature or humidity and do not require precision components.

iv. They have a superior performance-to-cost ratio.

Digital filters in LabVIEW have features to control parameter such as filter order, cutoff frequencies, amount of ripple, and stop band attenuation. LabVIEW offers wide range of Infinite Impulse Response (IIR) and Finite Impulse Response (FIR) filters such as Butterworth, Chebyshev, Chebyshev II or Inverse Chebyshev , Bessel, and Elliptic. The IIR and FIR filters are described briefly.

I. Infinite Impulse Response (IIR)

Infinite impulse response (IIR) is a property of digital signal processing systems. Systems having this property are identified as IIR systems. IIR system has an impulse response function which is non-zero through an infinite length of period. The IIR filters are different to finite impulse response (FIR) filters. FIR filters have fixed duration of impulse responses. The easiest analog IIR filter is an RC filter which is made up of a single resistor(R) supplied to a node then it is shared with an only one capacitor(C). These filters have an exponential impulse response distinguished by an RC time constant. Because the exponential function is asymptotic to a limit, and thus never settles at a fixed value, the response is considered infinite.

In digital IIR filters, the output feedback of the filter is immediately traceable in the equations which are defining the output. It is very obvious that unlike FIR filters, it is mandatory to carefully judge the "time zero" case in which the outputs of the filter have not clearly explained. Design of digital IIR filters is usually dependent on their analog equivalents because there are ample of works, resources, and straightforward design techniques regarding analog feedback filter design. In general, when a digital IIR filter is be implemented, an analog filter (e.g. Chebyshev filter, butterworth filter, Elliptic filter) is first implemented and then it is converted to digital filter by applying discretization techniques such as Impulse invariance or bilinear transform. The Chebyshev filter, Butterworth filter, and the Bessel filter are all included in IIR filters. These filters are explained with a precise manner in the following sections.

I.A Butterworth Filter

The Butterworth filter is a form of signal processing filter considered to have as flat a frequency response as possible in the pass band. It is also referred to as a maximally flat magnitude filter. An ideal electrical filter should have uniform sensitivity for the wanted frequencies and also completely reject the redundant frequencies. Such an ideal filter cannot be achieved but it is shown in succession closer approximations were obtained with increasing numbers of filter elements of the right values. At the time, filters generated considerable ripple in the pass band, and the choice of component values was highly interactive. Butterworth showed that a low pass filter could be designed whose cut off frequency was normalized to 1 radian per second and whose frequency response (gain) is given the following equation

$$\text{Gain} = G(\omega) = \sqrt{(1/1 + \omega 2n)}. \quad \text{.......(1)}$$

Where, ω= Angular frequency.

N=Number poles in the filter.

II. Finite Impulse Response (FIR)

In a signal processing system, as finite impulse response (FIR) filter settles to zero in finite duration of time, the impulse response of the filter is of finite duration. This is opposite to infinite impulse response (IIR) filters because it has internal feedback and may persists to respond indefinitely.FIR filters can be analog or digital and discrete-time or continuous-time in nature. The term digital filter is introduced because these filters are operated on discrete-time signals.

The simplest FIR filters which is a 3 term moving average filter which is given in the following equation.

$$Y(n) = (x[n+1] + x[n] + x[n-1]) \quad \text{.......(2)}$$

3.5 Band Pass Filter

A band pass filter is an electronic device or circuit that allows signals between two specific frequencies to pass, but that discriminates against signals at other frequencies. Some band pass filters require an external source of power and employ active components such as transistors and integrated circuits; these are known as active band pass filters.

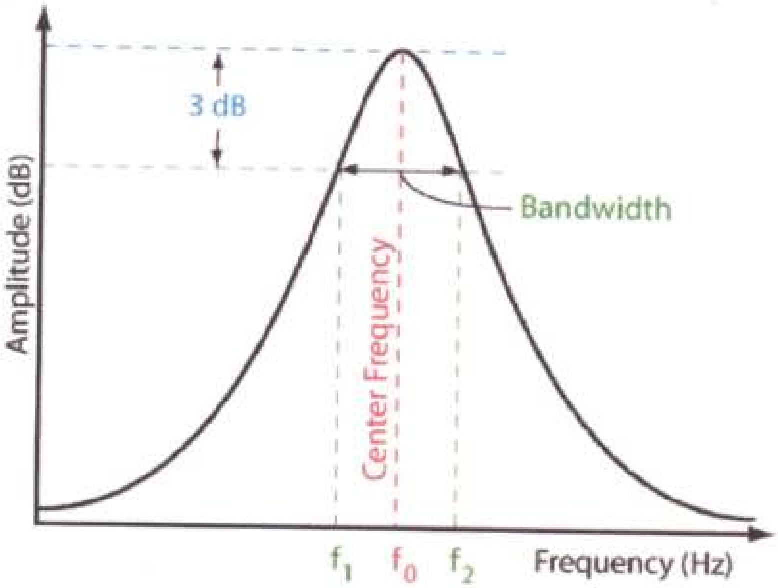


Figure 9: Band Pass Filter

3.6 Windowing

In practical application only a finite number of samples of the signal are obtained. When the DFT or FFT is used to extract the frequency content of a signal, it is intrinsically assumed that the data is a single period of a periodically repeating waveform. Leakage exists because of the finite time record of the input signal. An appropriate window is usually selected so as to reduce the spectral leakage. That is by applying a smoothing window function to the data before it is discrete-time Fourier transformed can greatly minimize spectral leakage.

3.6.1 Hanning Window

The Hanning window named after Julius von Hann and also known as the Hanning (for being similar in name and form to the Hamming window), von Hann and the raised cosine window is defined by the following equations 3.6 and 3.7

$$W(n) = 0.5(1-\cos(2\pi n/N-1)) \quad (3)$$

The untagged version is given by

$$W_o(n) = 0.5(1+\cos(2\pi n/N-1)) \quad (4)$$

3.6.2 Hamming Window

The window with these particular coefficients was proposed by Richard W. Hamming. This window is optimized to reduce the maximum side lobe for providing it a height of about one-fifth that of the Hann window. The hamming window function is expressed by the following equation 3.8.

$W(n)=\alpha-\beta(2\pi n/N-1$ .... (5)

Where, $\alpha=0.54$

$\beta=1-\alpha=0.46$

The unlagged version is given by

$W_o(n)=W(n+N-1/2)$ ....(6)

$=0.54+o.46\cos(2\pi n/N-1)$

CHAPTER 4

4 MATHEMATICAL CALCULATION AND RESULT

4.1 Calculation for Acceleration, Velocity and Displacement

All waveform graph indicators of "Y" scale provide the amplitude value for each signal or frequency. It is the real time signal but overall measurements using the root mean square (RMS) are the most common vibration measurement in the use. It is important to measure the true RMS not the mean. So the real time data must be converted into RMS suffix.

Many times it is necessary to change between suffixes.

Pk-Pk / 2 = Peak.. (7)

Peak x 0.707 = RMS.. (8)

RMS x 1.414 = Peak.. (9)

Peak x 2 = Pk-Pk.. (10)

The acceleration is obtained in inch/s^2 unit from mv/g as per following calculation.

1g = 32.2 feet/second^2... (11)

$$\frac{32.2\ \text{feet}^*\ 12\text{inches}}{\text{Second}^\wedge 2\ ^*\ \text{foot}}$$

1G = 386.1 inches/second^2.. (12)

In many cases we are confronted with Acceleration, Velocity, or Displacement, but are not pleased with it. Maybe we have acquired the measurement in acceleration, but the model demands for displacement. Maybe we have taken the data in displacement, but the manufacturer quoted the equipment specifications in velocity. With below mention calculation we can change between these EU's.

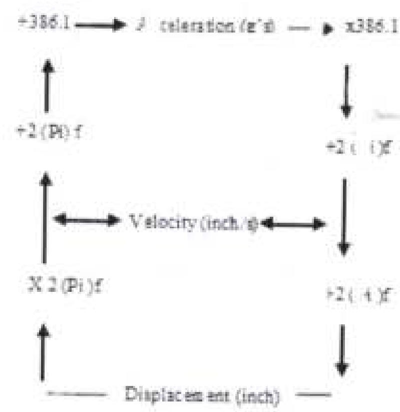


Figure 10: Conversion Chart between Three Big Vibration EU's.

4.2 Bearing Frequency Calculation

Two sets of experiment are conducted first with healthy bearing and second with the defective bearings installed in the mechanical system. If there is fault on the inner/outer raceway, the rolling element pass over the defect point which produces impulse while rotating on the machine at a given frequency. This frequency is known as a characteristics frequency, f_{bng} is associated with different type of bearing faults. Because of the periodicity occurrence of the abnormal physical phenomenon related to the existence of the fault. Characteristics frequencies are functions of the bearing geometry and the mechanical rotor frequency f_r .the outer race fault frequency for vibration f_{bng} is given as

$$f_{bng} = N_b \times \omega_{inner}\left(\frac{1-\frac{d}{D}\cos\alpha}{2}\right) \quad (13)$$

Where, N_b= No. of balls,

ω_{inner} =Shaft speed.

d=Ball diameter.

D=Pitch diameter.

α =Contact angle of the bearing.

In the experiment it is found that,

$N_b = 8$, $\omega_{inner} = 2800$ rpm= 46.6 Hz, d = 6 mm, D = 25 mm, $\alpha = 0°$

Now,

$$f_{bng} = 8 \times 46.6\left(\frac{1-\frac{6}{25}\cos 0}{2}\right) \quad (14)$$

$$f_{bng} = 141.6 \text{ Hz} \quad (15)$$

So, the f_{bng} of a healthy bearing frequency must not greater than 141.6 Hz.

4.3 Result of Vibration Signal Analysis

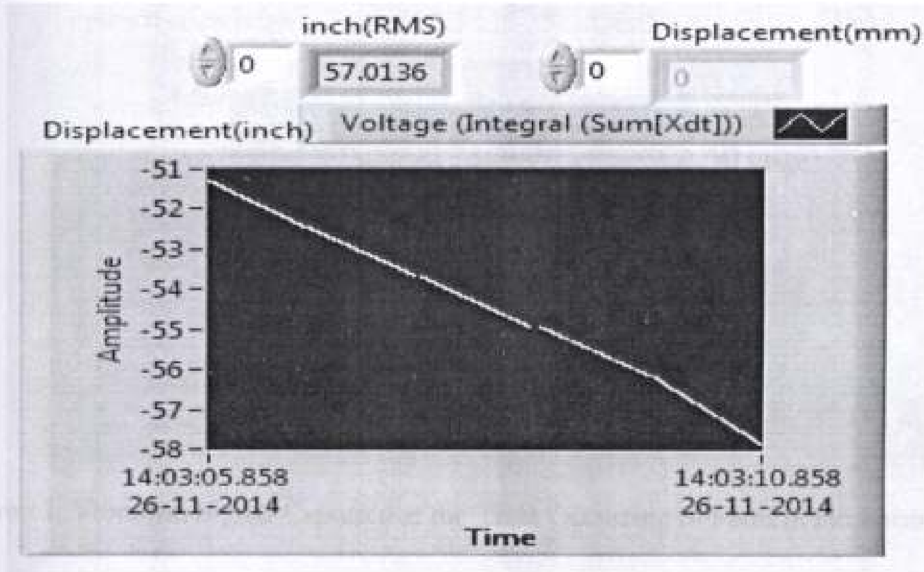


Figure 11: LabVIEW Front Panel of Displacement Measurement

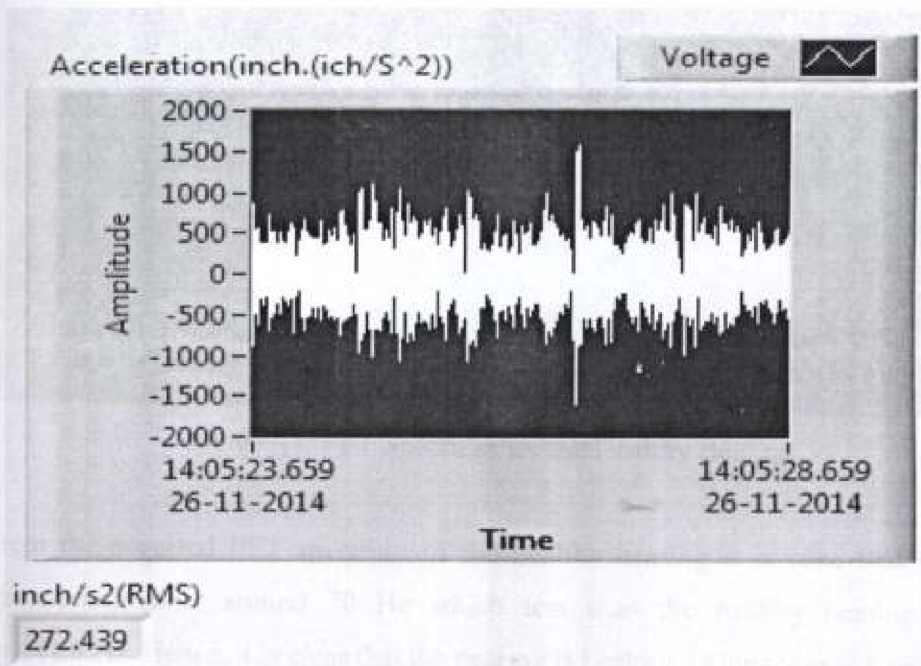


Figure 12: Vibration Signal Captured at the Time Occurring of Fault in the Form of Acceleration.

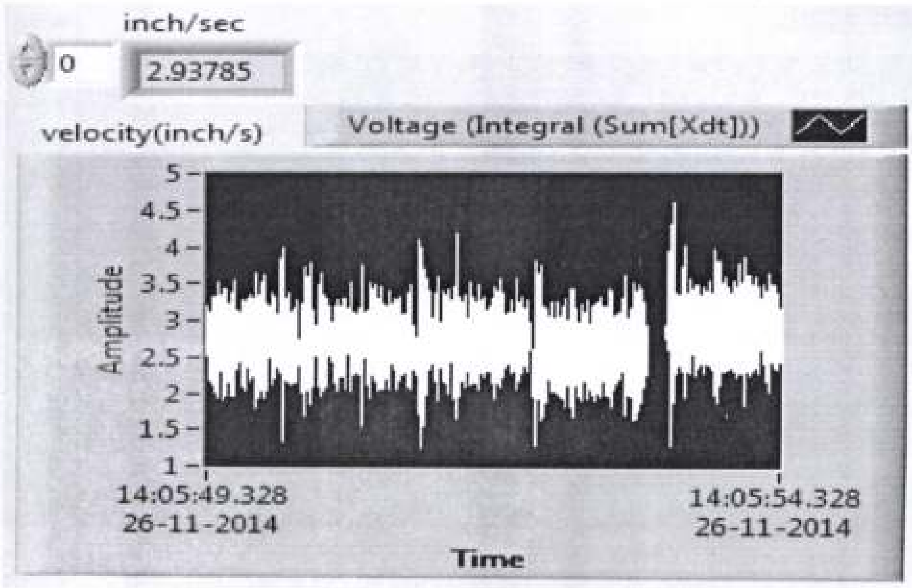


Figure 13: Vibration Signal Captured at the Time Occurring of Fault in the Form of Velocity.

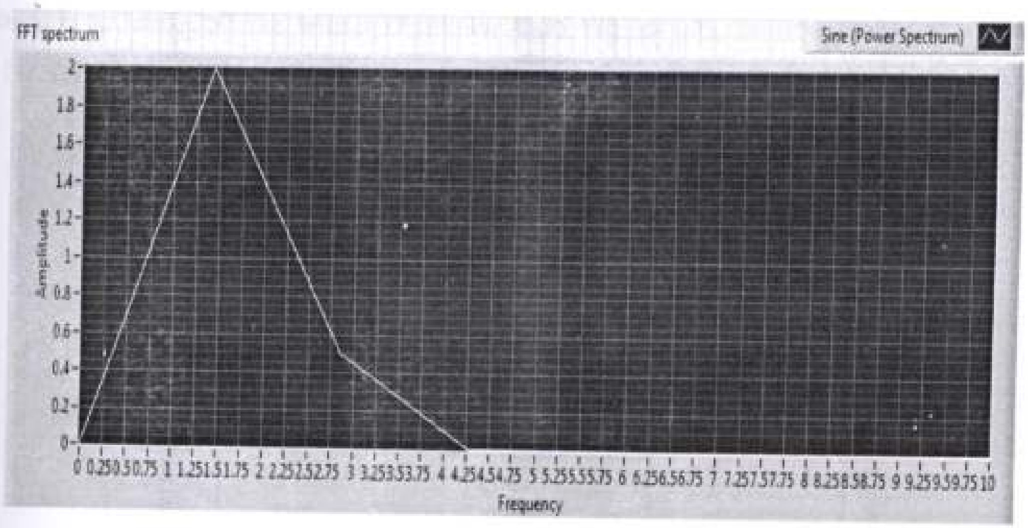


Figure 14: FFT Spectrum for the Healthy Bearing

From the acquired FFT spectrum of the healthy bearing it is seen that the bearing frequency approximately around 70 Hz which less than the healthy bearing maximum frequency 141.6 Hz. Hence, it is clear that the bearing is healthy. (Along x axis 1 small division = 10 Hz and along y axis 1 small division = 0.2 volt).

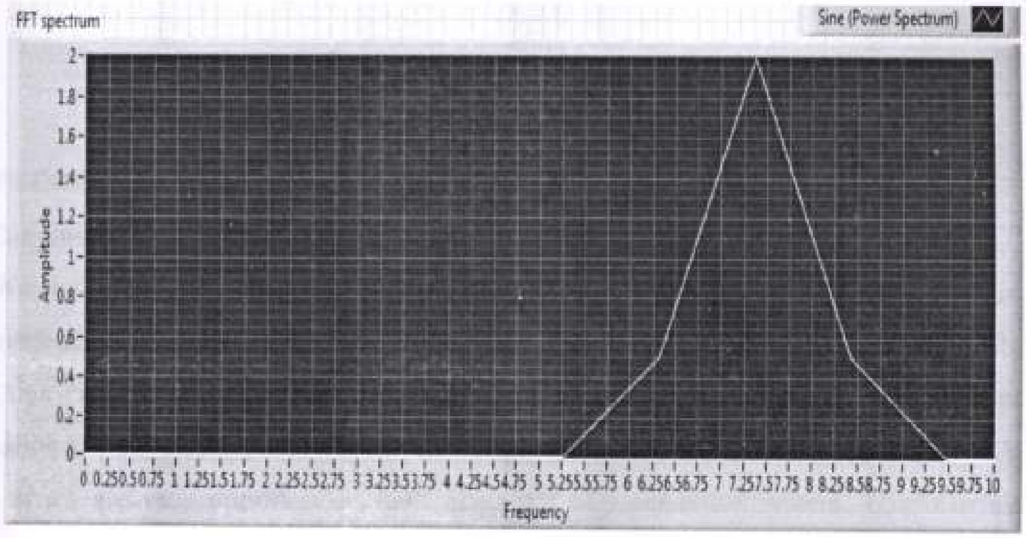


Figure 15: FFT Spectrum for the Faulty Bearing

From the acquired FFT spectrum of the faulty bearing it is seen that the bearing frequency is around 350 Hz which is greater than the healthy bearing maximum frequency 141.6 Hz. (Along x axis 1 small division = 10 Hz and along y axis 1 small division = 0.2 volt).

CHAPTER 5

5.1 Conclusion

We had approach systematic to measure vibration signal in the real time system. This measurement is automated with one button click. Computer acquires the data from vibration sensor, and mathematical analysis is performed in Lab-view vibration. User can get the information about velocity, acceleration and displacement of vibration signal as well as its rms values which are very important in fault diagnosis of mechanical system. User can also get frequency domain analysis (FFT). This feature incorporated with versatility of the Lab-VIEW vibration measurement tool box. User can also diagnose the faulty bearing in comparison with the healthy bearing with the help of FFT spectrum generated from the vibration signal of the bearing. Most important, is that the acquired data allow the simultaneous solution of the governing equation that describes the theoretical model. This fundamental research helps to build real time vibration measurement system. Later on such system may be upgrade to measure real time vibration signals generated by industrial machinery which will be useful in making key decision for maintenance of machine.

5.2 Future Planning

In this project we displayed the vibration parameters in terms of acceleration, velocity and displacement using LabVIEW programming. Also we used the FFT tool in frequency domain analysis of vibration signal to diagnose the frequency range of healthy and faulty bearing. In future we will try to use these parameters and control the machine if any error or problem occurs.

REFERENCES

1. Sunita Mahanta" A Labview Based Data Acquisition System for Monitoring and Analysis of Vibration Signal" IEEE Xplore (2012-2013).
2. Heta S. Shah, Pujaben N. Patel, Shashank P. Shah, and Manish T. Thakker "8 Channel Vibration Monitoring and Analyzing System Using LabVIEW" at Nirma University International Conference on Engineering in 2013.
3. Sukhjeet Sing, Amit Kumar, Navin Kumar "Motor Current Signature Analysis for Bearing Fault Detection in Mechanical Systems" in 3rd International Conference on Materials Processing and Characterization 2014.
4. S. A. McInerny and Y. Dai "Basic Vibration Signal Processing for bearing Fault Detection" IEEE Transactions On Education, Vol. 46, No. 1, February 2003

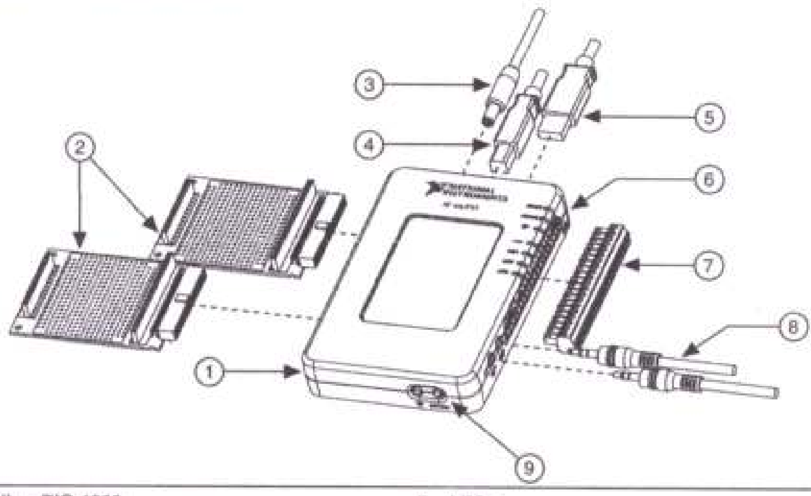
APPENDIX: A

USER GUIDE AND SPECIFICATIONS

NI myRIO-1900

The National Instruments myRIO-1900 is a portable reconfigurable I/O (RIO) device that students can use to design control, robotics, and mechatronics systems. This document contains pinouts, connectivity information, dimensions, mounting instructions, and specifications for the NI myRIO-1900.

Figure 1. NI myRIO-1900



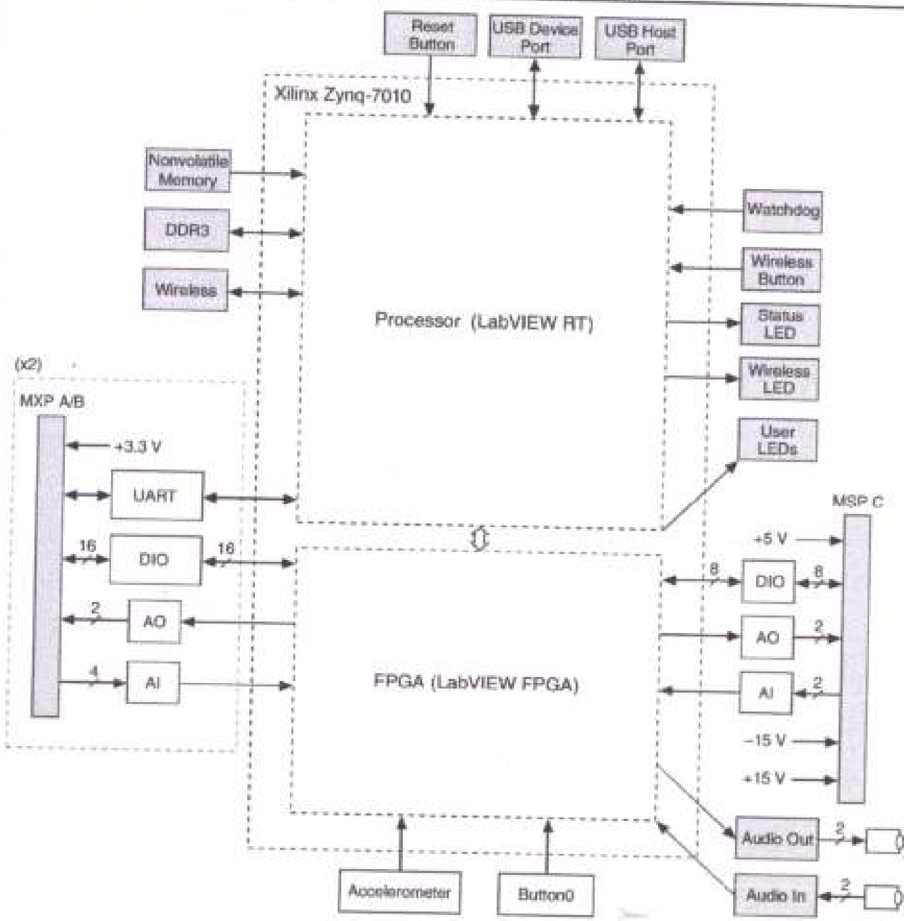
1 NI myRIO-1900
2 myRIO Expansion Port (MXP) Breakouts (One Included in Kit)
3 Power Input Cable
4 USB Device Cable
5 USB Host Cable (Not Included in Kit)
6 LEDs
7 Mini System Port (MSP) Screw-Terminal Connector
8 Audio In/Out Cables (One Included in Kit)
9 Button0

Hardware Overview

The NI myRIO-1900 provides analog input (AI), analog output (AO), digital input and output (DIO), audio, and power output in a compact embedded device. The NI myRIO-1900 connects to a host computer over USB and wireless 802.11b,g,n.

The following figure shows the arrangement and functions of NI myRIO-1900 components.

Figure 2. NI myRIO-1900 Hardware Block Diagram



Connector Pinouts

NI myRIO-1900 Expansion Port (MXP) connectors A and B carry identical sets of signals. The signals are distinguished in software by the connector name, as in `ConnectorA/DIO1` and `ConnectorB/DIO1`. Refer to the software documentation for information about configuring and using signals. The following figure and table show the signals on MXP connectors A and B. Note that some pins carry secondary functions as well as primary functions.

Figure 3. Primary/Secondary Signals on MXP Connectors A and B

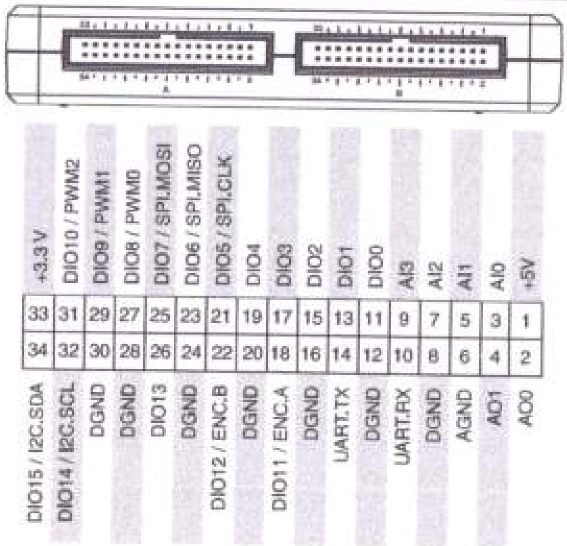


Table 1. Descriptions of Signals on MXP Connectors A and B

Signal Name	Reference	Direction	Description
+5V	DGND	Output	+5 V power output.
AI <0..3>	AGND	Input	0-5 V, referenced, single-ended analog input channels. Refer to the *Analog Input Channels* section for more information.
AO <0..1>	AGND	Output	0-5 V referenced, single-ended analog output. Refer to the *Analog Output Channels* section for more information.
AGND	N/A	N/A	Reference for analog input and output.
+3.3V	DGND	Output	+3.3 V power output.
DIO <0..15>	DGND	Input or Output	General-purpose digital lines with 3.3 V output, 3.3 V/5 V-compatible input. Refer to the *DIO Lines* section for more information.
UART.RX	DGND	Input	UART receive input. UART lines are electrically identical to DIO lines.
UART.TX	DGND	Output	UART transmit output. UART lines are electrically identical to DIO lines.
DGND	N/A	N/A	Reference for digital signals, +5 V, and +3.3 V.

The following figure and table show the signals on Mini System Port (MSP) connector C. Note that some pins carry secondary functions as well as primary functions.

Figure 4. Primary/Secondary Signals on MSP Connector C

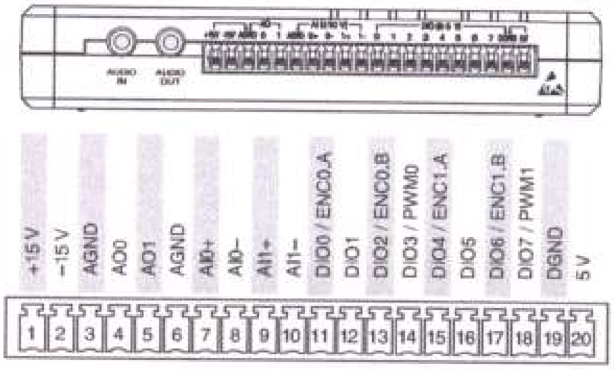
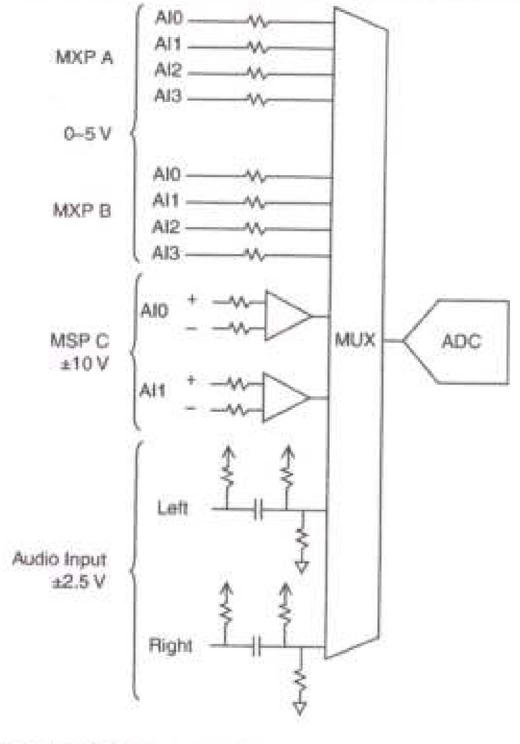


Table 2. Descriptions of Signals on MSP Connector C

Signal Name	Reference	Direction	Description
+15V/-15V	AGND	Output	+15 V/-15 V power output.
AI0+/AI0-; AI1+/AI1-	AGND	Input	±10 V, differential analog input channels. Refer to the *Analog Input Channels* section for more information.
AO <0..1>	AGND	Output	±10 V referenced, single-ended analog output channels. Refer to the *Analog Output Channels* section for more information.
AGND	N/A	N/A	Reference for analog input and output and +15 V/-15 V power output.
+5V	DGND	Output	+5 V power output.
DIO <0..7>	DGND	Input or Output	General-purpose digital lines with 3.3 V output, 3.3 V/5 V-compatible input. Refer to the *DIO Lines* section for more information.
DGND	N/A	N/A	Reference for digital lines and +5 V power output.

Figure 5 shows the analog input topology of the NI myRIO-1900.

Figure 5. NI myRIO-1900 Analog Input Circuitry



Analog Output Channels

The NI myRIO-1900 has analog output channels on myRIO Expansion Port (MXP) connectors A and B, Mini System Port (MSP) connector C, and a stereo audio output connector. Each analog output channel has a dedicated digital-to-analog converter (DAC), so they can all update simultaneously. The DACs for the analog output channels are controlled by two serial communication buses from the FPGA. MXP connectors A and B share one bus, and MSP connector C and the audio outputs share a second bus. Therefore, the maximum update rate is specified as an aggregate figure in the *Analog Output* section of the *Specifications*.

MXP connectors A and B have two analog output channels per connector, AO0 and AO1, which you can use to generate 0-5 V signals. MSP connector C has two analog output channels, AO0 and AO1, which you can use to generate signals up to ±10 V. The audio outputs are left and right stereo line-level outputs capable of driving headphones.

⚠ **Caution** Before using headphones to listen to the audio output of the NI myRIO-1900, ensure that the audio output is at a safe level. Listening to audio signals at a high volume may result in permanent hearing loss.

Figure 6 shows the analog output topology of the NI myRIO-1900.

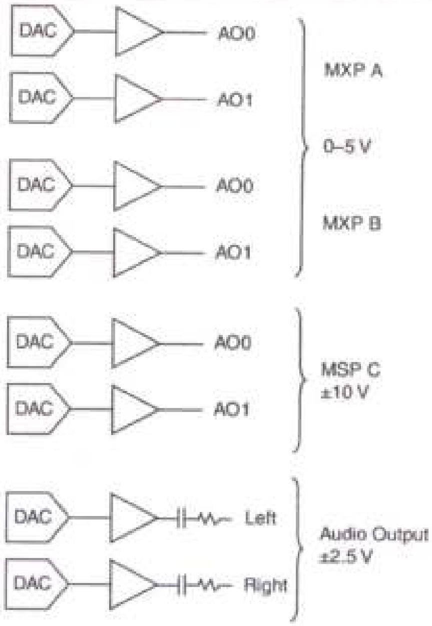


Figure 6. NI myRIO-1900 Analog Output Circuitry

Accelerometer

The NI myRIO-1900 contains a three-axis accelerometer. The accelerometer samples each axis continuously and updates a readable register with the result. Refer to the *Accelerometer* section of the *Specifications* for the accelerometer sample rates.

Converting Raw Data Values to Voltage

You can use the following equations to convert raw data values to volts:

$$V = Raw\ Data\ Value * LSB\ Weight$$

$$LSB\ Weight = Nominal\ Range \div 2^{ADC\ Resolution}$$

where *Raw Data Value* is the value returned by the FPGA I/O Node,

LSB Weight is the value in volts of the increment between data values,

Nominal Range is the absolute value in volts of the full, peak-to-peak nominal range of the channel,

and *ADC Resolution* is the resolution of the ADC in bits. (*ADC Resolution* = 12.)

- For AI and AO channels on the MXP connectors,

$$LSB\ Weight = 5\ \text{V} \div 2^{12} = 1.221\ \text{mV}$$

$$Maximum\ reading = 4095 * 1.221\ \text{mV} = 4.999\ \text{V}$$

- For AI and AO channels on the MSP connectors,

$$LSB\ Weight = 20\ \text{V} \div 2^{12} = 4.883\ \text{mV}$$

$$Maximum\ Positive\ Reading = +2047 * 4.883\ \text{mV} = 9.995\ \text{V}$$

$$Maximum\ Negative\ Reading = -2048 * 4.883\ \text{mV} = -10.000\ \text{V}$$

- For Audio In/Out,

$$LSB\ Weight = 5\ \text{V} \div 2^{12} = 1.221\ \text{mV}$$

$$Maximum\ Positive\ Reading = +2047 * 1.221\ \text{mV} = 2.499\ \text{V}$$

$$Maximum\ Negative\ Reading = -2048 * 1.221\ \text{mV} = -2.500\ \text{V}$$

- For the accelerometer,

$$LSB\ Weight = 16\ \text{g} \div 2^{12} = 3.906\ \text{mg}$$

$$Maximum\ Positive\ Reading = +2047 * 3.906\ \text{mg} = +7.996\ \text{g}$$

$$Maximum\ Negative\ Reading = -2048 * 3.906\ \text{mg} = -8.000\ \text{g}$$

DIO Lines

The NI myRIO-1900 has 3.3 V general-purpose DIO lines on the MXP and MSP connectors. MXP connectors A and B have 16 DIO lines per connector. On the MXP connectors, each DIO line from 0 to 13 has a 40 kΩ pullup resistor to 3.3 V, and DIO lines 14 and 15 have 2.2 kΩ pullup resistors to 3.3 V. MSP connector C has eight DIO lines. Each MSP DIO line has a 40 kΩ pulldown resistor to ground. DGND is the reference for all the DIO lines. You can program all the lines individually as inputs or outputs. Secondary digital functions include Serial Peripheral

Interface Bus (SPI), I2C, pulse-width modulation (PWM), and quadrature encoder input. Refer to the NI myRIO software documentation for information about configuring the DIO lines.

Figure 7. DIO Lines <13..0> on MXP Connector A or B

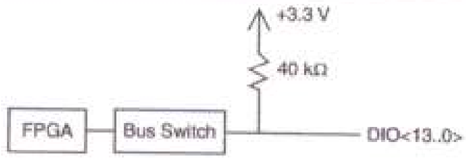


Figure 8. DIO Lines <15..14> on MXP Connector A or B

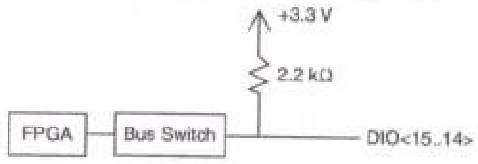
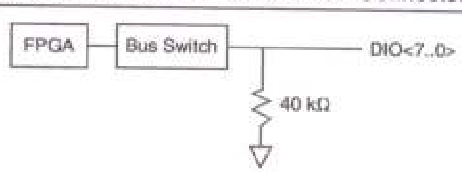


Figure 9. DIO Lines <7..0> on MSP Connector C



When a DIO line is floating, it floats in the direction of the pull resistor. A DIO line may be floating in any of the following conditions:

- when the myRIO device is starting up
- when the line is configured as an input
- when the myRIO device is powering down

You can add a stronger resistor to a DIO line to cause it to float in the opposite direction.

UART Lines

The NI myRIO-1900 has one UART receive input line and one UART transmit ouput line on each MXP connector. The UART lines are electrically identical to DIO lines 0 to 13 on the MXP connectors. Like those lines, UART.RX and UART.TX have 40 kΩ pullup resistors to 3.3 V. Use LabVIEW Real-Time to read and write over the UART lines.

Using the Reset Button

Pressing and releasing the Reset button restarts the processor and the FPGA.

Pressing and holding the Reset button for 5 seconds, then releasing it, restarts the processor and the FPGA and forces the NI myRIO-1900 into safe mode. In safe mode, the NI myRIO-1900 launches only the services necessary for updating configuration and installing software.

When the NI myRIO-1900 is in safe mode, you can communicate with it by using the UART lines on MXP connector A. You need the following items to communicate with the myRIO device over UART:

- USB-to-TTL serial UART converter cable (for example, part number TTL-232RG-VSW3V3-WE from FTD Chip)
- Serial-port terminal program configured with the following settings:
  - 115,200 bits per second
  - Eight data bits
  - No parity
  - One stop bit
  - No flow control

Using the Wireless Button and LED

For information about using the Wireless button, go to `ni.com/info` and enter the Info Code `myriowirelessbutton`.

For information about using the Wireless LED, go to `ni.com/info` and enter the Info Code `myriowirelessled`.

Using Button0

Button0 produces a logic TRUE when depressed and a logic FALSE when not depressed. Button0 is not debounced.

Understanding LED Indications

Power LED

The Power LED is lit while the NI myRIO-1900 is powered on. This LED indicates that the power supply connected to the device is adequate.

Status LED

The Status LED is off during normal operation. The NI myRIO-1900 runs a power-on self test (POST) when you apply power to the device. During the POST, the Power and Status LEDs turn on. When the Status LED turns off, the POST is complete. The NI myRIO-1900 indicates specific error conditions by flashing the Status LED a certain number of times every few seconds, as shown in Table 4.

Table 4. Status LED Indications

Number of Flashes Every Few Seconds	Indication
2	The device has detected an error in its software. This usually occurs when an attempt to upgrade the software is interrupted. Reinstall software on the device.
3	The device is in safe mode.
4	The software has crashed twice without rebooting or cycling power between crashes. This usually occurs when the device runs out of memory. Review your RT VI and check the memory usage. Modify the VI as necessary to solve the memory usage issue.
Continuously flashing or solid	The device has detected an unrecoverable error. Contact National Instruments.

LEDs 0-3

You can use LEDs 0-3 to help debug your application or easily retrieve application status. Logic TRUE turns an LED on and logic FALSE turns an LED off.

Using the USB Host Port

The NI myRIO-1900 USB host port supports Web cameras that conform to the USB Video Device Class (UVC) protocol as well as machine vision cameras that conform to the USB3 Vision standard and are USB 2.0 backward compatible. The NI myRIO-1900 USB host port also supports Basler ace USB3 cameras.

The NI myRIO-1900 USB host port also supports USB Flash drives and USB-to-IDE adapters formatted with FAT16 and FAT32 file systems. LabVIEW usually maps USB devices to the `/U`, `/V`, `/W`, or `/X` drive, starting with the `/U` drive if it is available.

NI myRIO-1900 Physical Dimensions

Figure 10. NI myRIO-1900 Dimensions, Front

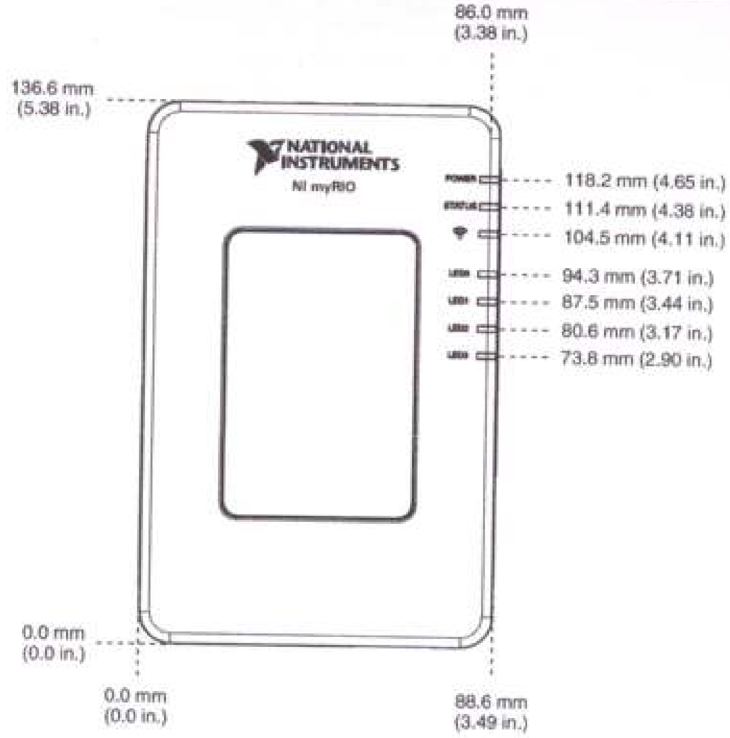


Figure 11. NI myRIO-1900 Dimensions, Back

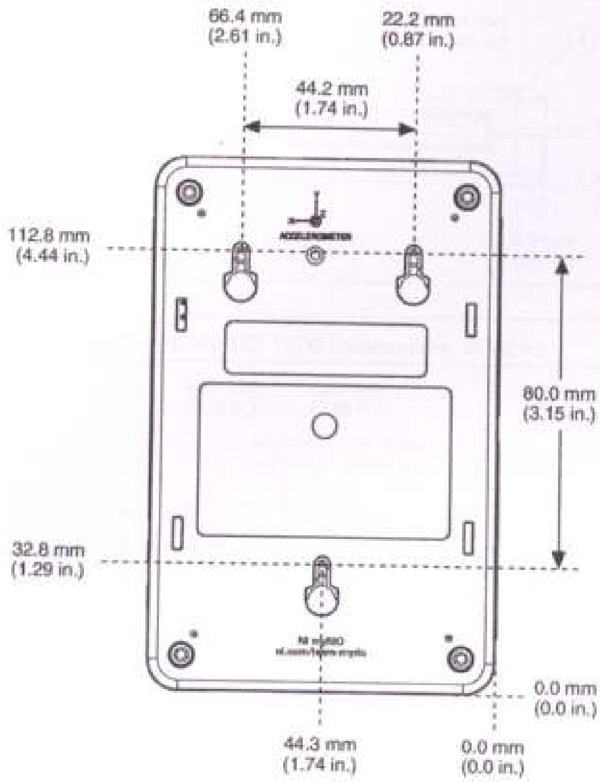
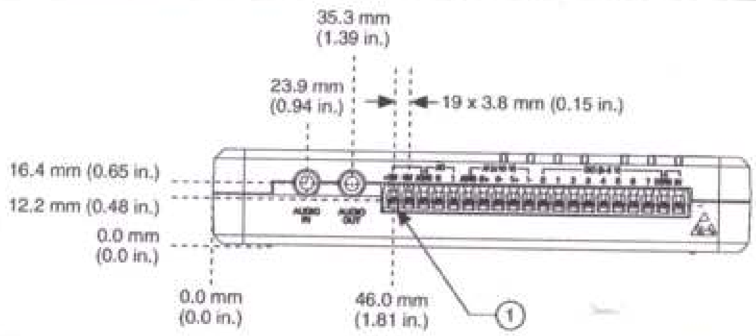
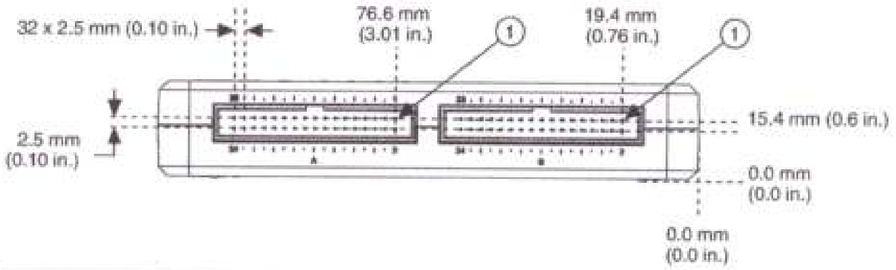


Figure 12. NI myRIO-1900 Dimensions, MSP Side



1 Pin 1

Figure 13. NI myRIO-1900 Dimensions, MXP Side



1 Pin 1

Figure 14. NI myRIO-1900 Dimensions, I/O End

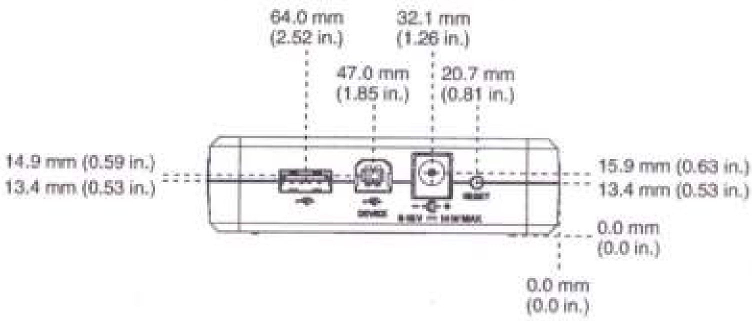
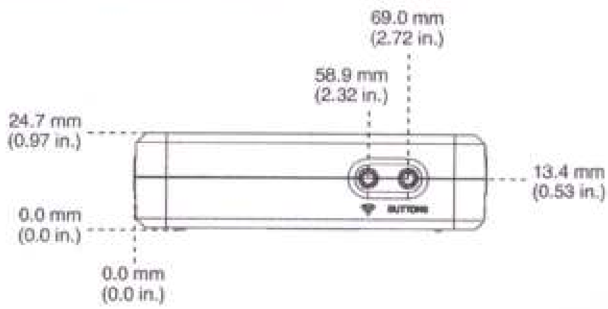


Figure 15. NI myRIO-1900 Dimensions, User End

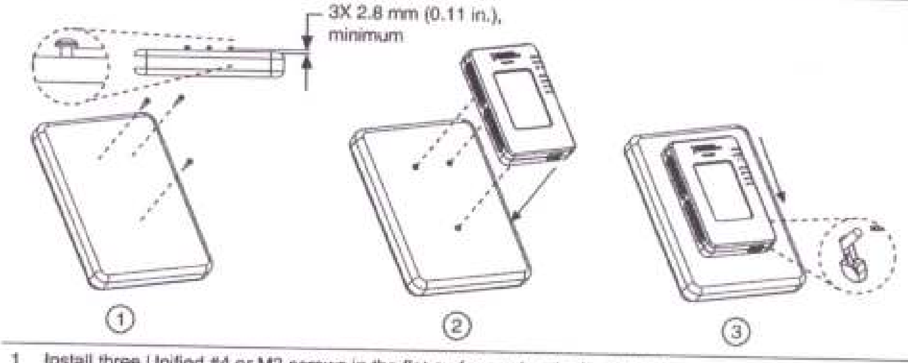


Mounting the NI myRIO-1900

Mounting the NI myRIO-1900 Using the Key Holes

You can use the provided key holes on NI myRIO-1900 to mount the device on a flat surface. Install the NI myRIO-1900 as shown in Figure 16. Use Unified #4 or ISO M3 screws to mount the NI myRIO-1900 using the key holes. Panhead screws are suitable for use with the NI myRIO-1900 key holes.

Figure 16. Mounting the NI myRIO-1900 Using the Key Holes

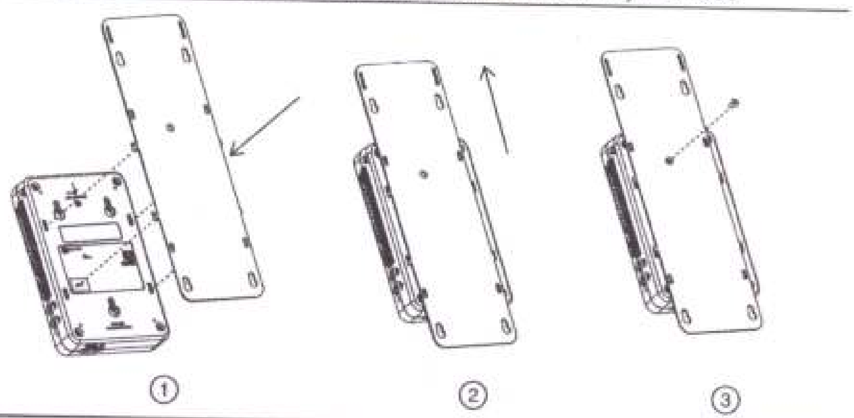


1 Install three Unified #4 or M3 screws in the flat surface using the key hole dimensions of the NI myRIO-1900 as a guide. Refer to Figure 11 for NI myRIO-1900 key hole dimensions. Leave a minimum spacing of 2.8 mm (0.11 in.) between the flat surface and the screw heads.
2 Place the NI myRIO-1900 on the screw heads.
3 Slide the NI myRIO-1900 down to secure the key holes on the screw heads.

Mounting the NI myRIO-1900 Using the Panel Mounting Kit

You can use the Panel Mounting Kit for NI myRIO-1900 to mount the device on a flat surface such as a panel or wall. Install the panel mounting kit on the NI myRIO-1900 as shown in Figure 17.

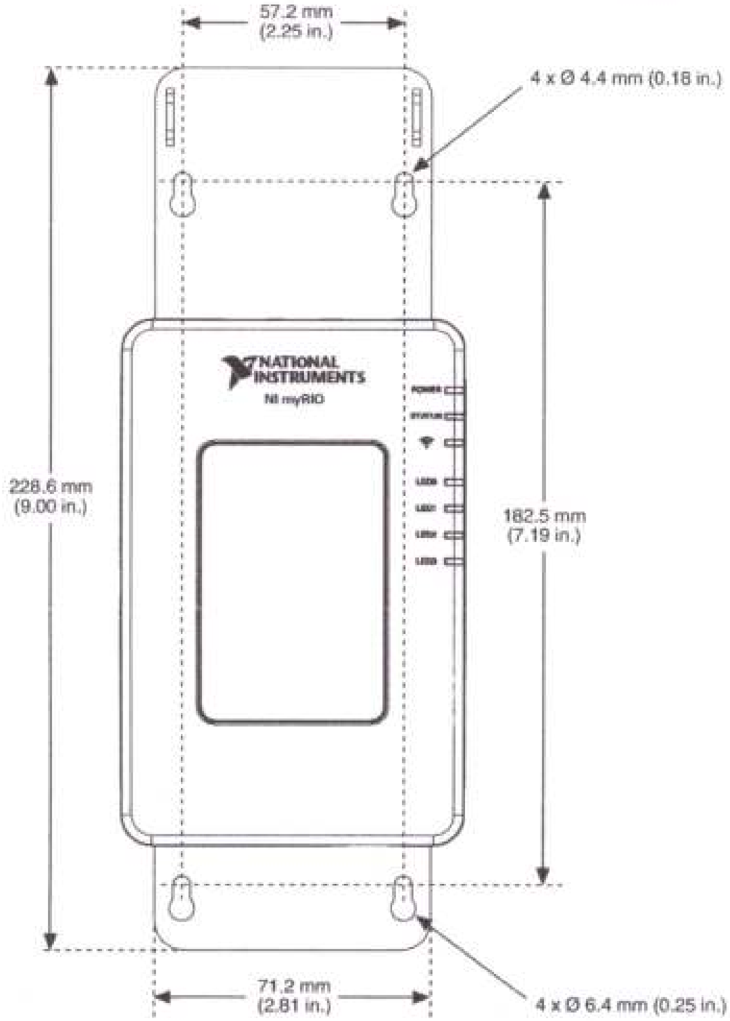
Figure 17. Installing the Panel Mounting Kit on the NI myRIO-1900



1 Place the panel on the back of the NI myRIO-1900
2 Slide the panel up to line up the screw holes on the panel and the NI myRIO-1900.
3 Secure the panel to the NI myRIO-1900. You must use the included 4-40 × 1/4 in. screw to attach the panel mounting kit to the NI myRIO-1900. Tighten the screw to 0.76 N · m (6.7 lb · in.) of torque. Do not exceed 0.87 N · m (7.7 lb · in.) of torque.

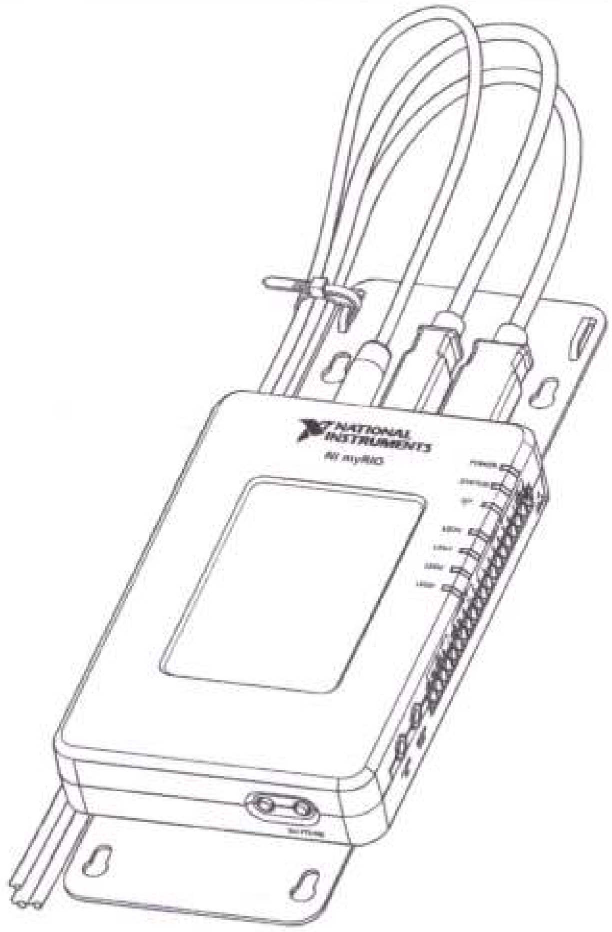
Fasten the panel mounting kit to the panel or wall using screws appropriate for the surface. The following figure shows the dimensions of the NI myRIO-1900 with the panel mounting kit installed.

Figure 18. Dimensions of NI myRIO-1900 with Panel Mounting Kit



Use a cable tie to secure the power and USB cables to the panel mounting kit as shown in Figure 19.

Figure 19. Securing the Power and USB Cables to the Panel Mounting Kit



Cables and Accessories

Table 5. Accessories Available from NI

Accessory	Description	NI Part Number
Power supply	Power supply for NI myRIO-1900	723403-01
MXP breakouts	Set of five MXP breakout boards for NI myRIO-1900	782696-01
MSP connector	MSP replacement connector plug for NI myRIO-1900	765788-01
Panel mounting kit	Panel mounting kit for NI myRIO-1900	783091-01

Specifications

The following specifications are typical for the 0 to 40 °C operating tempreature range unless otherwise noted.

Processor

Processor type .... Xilinx Z-7010

Processor speed .... 667 MHz

Processor cores 2

Memory

Nonvolatile memory .... 256 MB

DDR3 memory .... 512 MB

DDR3 clock frequency .... 533 MHz

DDR3 data bus width .... 16 bits

For information about the lifespan of the nonvolatile memory and about best practices for using nonvolatile memory, go to `ni.com/info` and enter the Info Code `SSDBP`.

FPGA

FPGA type .... Xilinx Z-7010

Wireless Characteristics

Radio mode .... IEEE 802.11 b,g,n

Frequency band .... ISM 2.4 GHz

Channel width .... 20 MHz

Channels	USA 1-11, International 1-13
TX power	+10 dBm max (10 mW)
Outdoor range	Up to 150 m (line of sight)
Antenna directivity	Omnidirectional
Security	WPA, WPA2, WPA2-Enterprise

USB Ports

USB host port	USB 2.0 Hi-Speed
USB device port	USB 2.0 Hi-Speed

Analog Input

Aggregate sample rate	500 kS/s
Resolution	12 bits
Overvoltage protection	±16 V
MXP connectors	
Configuration	Four single-ended channels per connector
Input impedance	>500 kΩ acquiring at 500 kS/s 1 MΩ powered on and idle 4.7 kΩ powered off
Recommended source impedance	3 kΩ or less
Nominal range	0 V to +5 V
Absolute accuracy	±50 mV
Bandwidth	>300 kHz
MSP connector	
Configuration	Two differential channels
Input impedance	Up to 100 nA leakage powered on; 4.7 kΩ powered off
Nominal range	±10 V
Working voltage (signal + common mode)	±10 V of AGND
Absolute accuracy	±200 mV
Bandwidth	20 kHz minimum, >50 kHz typical
Audio input	
Configuration	One stereo input consisting of two AC-coupled, single-ended channels
Input impedance	10 kΩ at DC
Nominal range	±2.5 V
Bandwidth	2 Hz to >20 kHz

Analog Output

Aggregate maximum update rates

- All AO channels on MXP connectors .... 345 kS/s
- All AO channels on MSP connector and audio output channels .... 345 kS/s

Resolution .... 12 bits

Overload protection .... ±16 V

Startup voltage .... 0 V after FPGA initialization

MXP connectors

- Configuration .... Two single-ended channels per connector
- Range .... 0 V to +5 V
- Absolute accuracy .... 50 mV
- Current drive .... 3 mA
- Slew rate .... 0.3 V/µs

MSP connector

- Configuration .... Two single-ended channels
- Range .... ±10 V
- Absolute accuracy .... ±200 mV
- Current drive .... 2 mA
- Slew rate .... 2 V/µs

Audio output

- Configuration .... One stereo output consisting of two AC-coupled, single-ended channels
- Output impedance .... 100 Ω in series with 22 µF
- Bandwidth .... 70 Hz to >50 kHz into 32 Ω load; 2 Hz to >50 kHz into high-impedance load

Digital I/O

Number of lines

- MXP connectors .... 2 ports of 16 DIO lines (one port per connector); one UART.RX and one UART.TX line per connector
- MSP connector .... 1 port of 8 DIO lines

Direction control .... Each DIO line individually programmable as input or output

Logic level .... 5 V compatible LVTTL input; 3.3 V LVTTL output

Input logic levels

Input low voltage, V_{IL} .... 0 V min; 0.8 V max

Input high voltage, V_{IH} .... 2.0 V min; 5.25 V max

Output logic levels

Output high voltage, V_{OH}
sourcing 4 mA .... 2.4 V min; 3.465 V max

Output low voltage, V_{OL}
sinking 4 mA .... 0 V min; 0.4 V max

Minimum pulse width .... 20 ns

Maximum frequencies for secondary digital functions

SPI .... 4 MHz

PWM .... 100 kHz

Quadrature encoder input .... 100 kHz

I^2C .... 400 kHz

UART lines

Maximum baud rate .... 230,400 bps

Data bits 5, 6, 7, 8

Stop bits 1, 2

Parity .... Odd, Even, Mark, Space

Flow control .... XON/XOFF

Accelerometer

Number of axes 3

Range .... ±8 g

Resolution .... 12 bits

Sample rate .... 800 S/s

Noise .... 3.9 mg_{rms} typical at 25 °C

Power Output

+5 V power output

Output voltage .... 4.75 V to 5.25 V

Maximum current on each connector .... 100 mA

+3.3 V power output

Output voltage .... 3.0 V to 3.6 V

Maximum current on each connector .... 150 mA

+15 power output

Output voltage .... +15 V to +16 V

Maximum current .... 32 mA (16 mA during startup)

-15 V power output

Output voltage .... -15 V to -16 V

Maximum current .... 32 mA (16 mA during startup)

Maximum combined power from +15 V and -15 V power output .... 500 mW

Power Requirements

NI myRIO-1900 requires a power supply connected to the power connector.

Caution You must use either the power supply provided in the shipping kit, or another UL Listed ITE power supply marked *LPS*, with the NI myRIO-1900.

Power supply voltage range .... 6-16 VDC

Maximum power consumption .... 14 W

Typical idle power consumption .... 2.6 W

Environmental

To meet these specifications, you must operate the NI myRIO-1900 with the window facing away from the mounting surface and ensure that there is at least 1 in. of clearance in front of the window during use.

Ambient temperature near device (IEC 60068-2-1, IEC 600682-2) .... 0 to 40 °C

Storage temperature (IEC 60068-2-1, IEC 600682-2) .... -20 to 70 °C

Operating humidity (IEC 60068-2-56) .... 10 to 90% RH, noncondensing

Storage humidity (IEC 60068-2-56) .... 10 to 90% RH, noncondensing

Maximum altitude .... 2,000 m

Pollution Degree (IEC 60664) 2

Indoor use only.

Physical Characteristics

Weight .... 193 g (6.8 oz)

Safety

Safety Standards

This product is designed to meet the requirements of the following standards of safety for electrical equipment for measurement, control, and laboratory use:

- IEC 61010-1, EN 61010-1
- UL 61010-1, CSA 61010-1

Note For UL and other safety certifications, refer to the product label or the *Online Product Certification* section.

Caution Using the NI myRIO-1900 in a manner not described in this document may impair the protection the NI myRIO-1900 provides.

Hazardous Locations

The NI myRIO-1900 is not certified for use in hazardous locations.

Electromagnetic Compatibility

This product meets the requirements of the following EMC standards for electrical equipment for measurement, control, and laboratory use:

- EN 61326-1 (IEC 61326-1): Class A emissions; Basic immunity
- EN 55022 (CISPR 22): Group 1, Class A emissions
- EN 55011 (CISPR 11): Group 1, Class A emissions
- AS/NZS CISPR 11: Group 1, Class A emissions
- AS/NZS CISPR 22: Group 1, Class A emissions
- FCC 47 CFR Part 15B: Class A emissions
- ICES-001: Class A emissions

Note For EMC declarations and certifications, refer to the *Online Product Certification* section.

CE Compliance CE

This product meets the essential requirements of applicable European Directives as follows:

- 2006/95/EC; Low-Voltage Directive (safety)
- 2004/108/EC; Electromagnetic Compatibility Directive (EMC)
- 1999/5/EC; Radio and Telecommunications Terminal Equipment Directive (R&TTE)