

SIM University (UniSIM)
School of Science and Technology



BENG (HONS) IN ELECTRONICS (BEHE/12)

**A Study on Fault Detection and Diagnosis for Determining
Operational Reliability**

ENG499 – Capstone Project
Project No: Jul07/BEHE/SP/03

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Abstract

This Report covers the findings of various fault detection methods and the monitoring of operating characteristics of critical equipment in the manufacturing industries.

As for the valve diagnostic portion, the report will give an introduction to Foundation Fieldbus technology and NI Lookout software. Under the introduction Foundation Fieldbus technology, it includes the capabilities and purpose of this technology; the first part is connecting all field devices to the host system, which includes the installation and setting up of valve, calibration process, individual host system's methods and looking out for valve signature by using Lookout software.

For the motor portion, the report studies the fault diagnosis of DC motor by using National Instrument USB data acquisition device time-series models. The problem has been widely discussed in the literature and National Instrument USB data acquisition device have been used in the fault diagnosis of DC motors. Here National Instrument USB data acquisition device time-series models are created for the motor with different load condition.

Finally, for the conclusion section of both portions, it will conclude the research on the Foundation Fieldbus and National Instrument USB data acquisition device study, such as overviews on the two host system and the data measurement analysis. It will suggest what other functions or features can be added to make further improvements.

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Chapter 1

Introduction and Aims

1.1 Purpose

This report aims to explore various fault detection methods and diagnosis for monitoring the operating characteristics of critical equipment in manufacturing industries. To study real time monitoring and recording of control valve signature by using National Instruments Fieldbus Host systems and lookout software. And fault diagnosis of DC motor by using NI USB data acquisition device time-series models.

1.2 Background

If there were the signs of having trouble during the traditional operating procedure, it should take out the valve and took it back for repair. The valve was reinstalled if there wasn't a problem at all. But if there was a problem, the valve would be pulled out again. However, this project proposes to study a way for early detection of the fault before the point of failure by interpreting the signature of the device. We will compare the valve's current performance with its signature (a baseline taken when the valve was new) to discover how the basic feature have changed and whether that change will affect the whole operation if a valve seems to be malfunctioning. The operators could search other possibilities if the valve is in good condition. The maintenance decision will be made according to factual information and not gut-feel.

Some useful tests may also be applied to verify if the control valve is functioning effectively. The valve signature, which is mentioned in the previous section, will be carried out when a valve is new. A record of its performance, trending of the travel distance when opening and closing versus the pressure applied is made. As this project propose to overlay the results on the original, determine actuator spring rate and valve friction to decide if degradation has happened such as problems with packing. Other invested characteristics include the step response test which is for evaluating how well the valve tracks an input change. Process control may be greatly enhanced in order to minimize dead time, dead band and overshoot. Hysteresis, dead

band and dynamic error are analyzed by the Dynamic Error Band diagnostic while the calculation of friction, spring rate and other parameters are useful in getting the best possible view into the health of the valve.

The motor performs dependably under heavy or prolonged use in the industries. The issues of preventive and condition-based maintenance, online monitoring, system fault detection, diagnosis, and prognosis are more and more important. A technique is introduced that discern faults in DC motors. This project describes the results of detecting fault using vibration signature analysis.

1.3 Project objective

This project investigates various fault detection methods and to monitoring the operating characteristics of critical equipment in the manufacturing industries. The valves are complex mechanical devices which require periodic careful adjustments or repair to maintain operational readiness. Valve diagnostic application may be easily carried out by using Lookout and Foundation fieldbus to develop. This project investigates useful sample use fieldbus software for diagnostic purpose. With the Lookout and OPC, allow us very easily to develop valve diagnostics applications.

Various methods have been applied in the past to motor-operated devices which include different signature analysis methods, such as vibration signature analysis, direct measured mechanical load-time traces and the like.

In the use of vibration signature analysis, special purpose sensors, usually accelerometers are mounted on the equipment being monitored, which also requires access to the equipment to mount the sensors during testing. The location and orientation of the accelerometers are critical to the characteristics of the signal obtained. A vibration generated in one part of the mechanical device is altered as it is transmitted through the solids (usually metallic) separating the source from the accelerometer. Thus, the interpretation of a vibration signal is complicated by

requiring knowledge of the vibration transmission characteristics of the equipment. In addition, the analysis of the vibration signals taken at different times (in order to detect changes) is dependent on the ability to reproduce the precise location and direction of mounting of the accelerometers. Thus, in most cases, accelerometers and/or their mounting fixtures are permanently installed on the equipment to be monitored.

In addition, accelerometers will sense sources of vibration which are not generated by the drive motor or the device being driven by the motor which is being evaluated. Not only will these vibration sources affect accuracy and precision, they are in general not an influence on the condition of the equipment, and thus represent extraneous and unnecessary information which must be dealt with.

Accelerometers themselves are subject to degradation if exposed to harsh environments, such as in the containment of nuclear power plants. Their accuracy or precision can be influenced by environmental conditions such as temperature, humidity, nuclear radiation, acoustic noise, corrosive substances, electromagnetic interference, and the like. Although in some cases the effects of one or more of these factors can be removed or compensated for, they represent a significant potential source of error, especially in nuclear plant containment environments.

Therefore, it will be obvious from the above discussion that present signature analysis methods are limited and require additional hardware to be attached to the device during testing. These methods are especially limited when used in diagnosing electric motor-operated devices, such as motor-operated and the like in hostile environments. The tests are limited to times when the plants, in which the devices are used. As a result, most of the information provided by testing under these conditions does not address device operational readiness directly, but rather certain abnormalities that could potentially lead to loss of operational readiness.

In order to provide diagnostic information about operational readiness of an electric motor-driven device, especially those types which are inaccessible during normal operation, the magnitudes and types of abnormalities and their rates of change (trends) with time need to be determined. This allows a judgment to be made as to when corrective action should be taken to prevent loss of operational readiness. In order to obtain this type of diagnostic information, signatures need to be obtained continuously or at least during scheduled periods of normal operation of the device for comparison with previous signatures to not only obtain the current status of the magnitude of abnormalities, but also provide trending information.

Thus, it will be seen that there is a need for a signature analysis method for remotely monitoring the operating characteristics of an electric motor-operated device which does not require access to the device or additional hardware to be attached to the device during monitoring.

1.4 Methodology

The information for this report was obtained through lab sheet, internet, manuals, books and through own research. Also by register in the NI forum in order to rectify some problem faced in this project.

Chapter 2

Valve Signature Diagnosis

2.1 Device Description(FY302)

The FY302 is part of Smar's complete 302 series of Foundation Fieldbus devices, which is from the first generation of Foundation Fieldbus devices. It's a control valve positioner for pneumatic valve in a Foundation Fieldbus system, the FY302 produces a pressure output as required to position a control valve according to an input received over the Foundation Fieldbus network or internal controller. The Foundation Fieldbus technology used in the FY302 enables, an easy interface between the field and the control room and several interesting features that considerably reduce the installation, operation and maintenance costs.

2.2 Foundation Fieldbus

Foundation Fieldbus is seen as many things by many people and some users incorrectly regard Foundation Fieldbus and device networks as one and the same. It is important to clearly understand the differences.

The growth of digital communication technology has led to a vast array of device-level network options, which can be categorized as either sensor/actuator bus networks or CAN-based I/O and control networks. While suitable for discrete automation tasks such as counting and sorting, these networks lack a User Layer that is necessary for PID and other process automation tasks.

Foundation Fieldbus, however, is an all-digital, serial, two-way communications system that interconnects measurement and control equipment such as sensors, actuators and controllers. At the base level in the hierarchy of plant networks, it serves as a Local Area Network (LAN) for instruments used in process control and manufacturing automation applications and has a built-in capability to distribute the control application across the network.

The demand for Foundation Fieldbus technology is being driven by manufacturing end users' desire to move away from older, centralized plant control strategies to distributed control in the field. End users want an enabling technology that provides true device interoperability, enhanced field-level control and reduced installation costs. Suppliers want to base their new product developments on an open, non-proprietary Foundation Fieldbus protocol that is available to any company that wishes to implement it.

2.2.1 Benefits of Foundation Fieldbus

Fieldbus is simpler and much user-friendly host system compared to the other host system. All the Fieldbus devices connected easily to the Fieldbus host system without any major problem and all devices appear on the host once they are connected to the Fieldbus network.

- Reduction of Hardware
- Installation with less wire
- Data Quantity & Quality
- Maintenance
- Interoperability

2.2.2 Foundation Fieldbus Blocks

Function blocks are standardized encapsulations of control functions such as analog inputs, analog outputs, and Proportional/ Integral/ Derivative control. Additional standard function blocks for process control include: discrete input, discrete output, proportional/ derivative controller, signal selector, manual loader, bias/gain station, and ratio station. Function blocks are built into the field devices as needed to achieve the desired device functionality.

For example, a simple temperature sensor will contain an AI function block in order to communicate its variables on the fieldbus. A valve might contain a PID function block as well as the expected AO block. Thus a complete control loop can be built using only a simple sensor and a valve since these two devices contain the required AI, PID and AO function blocks. The function block concept is consistent with the ISA and IEC standards work.

2.2.3 Communication Stack

➤ User Application – Blocks

The Fieldbus Foundation has defined a standard User Application based on “Blocks”. Blocks are representations of different types of application functions

➤ Resource Block

The resource block describes characteristics of the Fieldbus device such as the device name, manufacturer, and serial number. There is only one resource block in a device.

➤ Function Block

Function Block (FB) provides the control system behavior. The input and output parameters of Function Blocks can be linked over the Fieldbus. The execution of each Function Block is precisely scheduled. There can be many function blocks in a single User Application.

➤ Transducer Blocks

Transducer Blocks decouple Function Blocks from the local input/output function required to read sensors and command output hardware. They contain information such as calibration date and sensor type. There is usually one transducer block for each input or output function block.

2.2.4 About Fieldbus Technology

The increased competition and pressure on prices that affects all areas of production and process engineering means that all opportunities for rationalization must be exploited in full. One practice that has proved effective is the automation of processes using fieldbuses with the simultaneous reduction system startup time, and the time

required to adapt the system based on changing needs. Serial fieldbus technology offers numerous advantages compared with both parallel wiring, and vendor proprietary networks.

The growing degree of automation in machines and systems also increases the amount of cable required for parallel wiring due to the large number of I/O points. This brings with it-increased effort for configuration, installation, startup, and maintenance. The cable requirements are often high because, for example, special cables are required for the transmission of analog values. Parallel field wiring thus entails serious cost and time factors. In comparison, the serial networking of components in the field using fieldbus systems is much more cost-effective.

The fieldbus replaces the bundle of parallel cables with a single bus cable and connects all levels, from the field to the control level. Regardless of the type of automation device used, e.g., programmable logic controllers (PLCs) from various manufacturers or PC based control systems, the fieldbus transmission medium networks all components. They can be distributed anywhere in the field and are all connected locally. This provides a powerful communication network for today's rationalization concepts.

There are numerous advantages to a fieldbus system in comparison to parallel wiring: The reduced amount of cabling saves time during planning and installation, while the cabling, terminal blocks, and the control cabinet dimensions are also reduced. Selfdiagnostics, which are carried out by the system using plain text displays, minimize downtimes and maintenance times. Improved reliability and increased availability due to short signal paths play an important role, especially for critical signals. There is even greater protection from faults for analog values. Open fieldbus systems standardize data transmission and device connection regardless of the manufacturer.

The user is therefore independent of any manufacturer specific standards. The system can be easily extended or modified, offering flexibility as well as investment protection.

2.3 National Instrument Equipment

NI-Fbus is a simpler and much user-friendly host system compared to the others host system. All the fieldbus devices connected easily to the NI-Fbus host system without any major problem and all devices appear on the host once they are connected to the fieldbus network.

The NI-FBUS Configurator is used to configure a Foundation Fieldbus network and keep track of your configuration changes. The NI-FBUS Configurator is a graphical environment for creating linkages, loops, and a schedule.

A Foundation Fieldbus network is made up of devices connected by a serial bus. This serial bus is called a link (also known as a segment). A Fieldbus network consists of one or more links. Each link is configured with a unique link identifier.

Each link on the Fieldbus network connects physical devices. The devices can be field devices (temperature transmitters, valves, and so on) or host devices (PCs, distributed control systems). Each physical device is configured with a physical device tag, an address, and a device ID. The physical device tag must be unique within a Fieldbus system, and the address must be unique within each link. The device manufacturer assigns a device ID that is unique to the device.

Purpose of NI--FBUS Configurator

- Assignment of device tags and addresses.
- Assignment of function block tags.
- Configuration of function blocks linkages and execution schedules.
- Download/Upload configurations and schedules.

- On-line help using Device Description.

2.3.1 Look out

Lookout is a Human-Machine Interface (HMI) and Supervisory Control and Data Acquisition (SCADA) software package for industrial automation. Lookout runs under Windows and communicates with field I/O through control hardware. Typical Lookout applications include continuous process monitoring and supervisory control, discrete manufacturing, batch applications, and remote telemetry systems.

Lookout is a truly object-oriented system, with function such as PLC interfacing, trending and data logging encapsulated in configurable objects.

Lookout is a state-of-the-art HMI/SCADA software product that requires no programming or script writing. Available as a 32-bit version for Windows 2000/NT/9x, Lookout provides architecture for applications ranging from simple HMI to large, sophisticated networked SCADA systems. Lookout is a truly object-oriented system, with functions such as PLC interfacing, trending, and data logging encapsulated in configurable objects. Because Lookout objects encapsulated data and functional behavior, a PLC object, for example, contains the specific registers available within the PLC as well as the mechanism for communication with the PLC. This object-oriented approach results in higher productivity because the objects and their functions are easily configured at the same time. And the configuration of Lookout objects is truly online. Adding, deleting and modifying PLC and field I/O connections, graphics and supervisory control logic without shutting down critical manufacturing processes.

With the networking capability of Lookout, connecting multiple servers and multiple clients to control and monitor the process. Web browsers such as Internet Explorer can also be use to monitor as well as to control the process. Lookout is not only an OPC server but also an OPC client. Integration with other OPC hardware and

software is made seamless with this industry standard capability. All these easy-to-use capabilities increase the productivity.

Early Lookout installations were in water treatment plants and the oil fields of Texas. Because of this background, Lookout is especially adept at handling remote telemetry – based SCADA applications. Radio modem and dial-up communications are an integral part of the Lookout I/O driver architecture. Lookout accepts different protocols on the same serial port. When it comes to telemetry, Lookout offers genuine ease of use.

The key to the high performance of Lookout is its event – driven architecture. Lookout uses an event – driven approach in which individual objects generate events based on their configurations. Events normally occur as a result of changes in data from an I/O device, user input or some timed event. In the absence of such events, the Lookout system is totally quiescent. When an event occurs, the affected objects awaken to perform their functions, returning to their inactive state on completion. Thus, in-plant applications are responsive and make efficient use of system resources. For applications requiring fully configurable HMI, historical trending, event logging, alarm management, security, SQL and SPC, Lookout delivers high performance while bringing a new level of ease of use to system configuration.

2.3.2 Advantages of Lookout

National Instruments Lookout is an object-based automation software system that delivers unparalleled power and ease of use in demanding industrial automation and measurement applications. To develop an application, no matter how complicated, only dragging and dropping objects and connecting them is required only. There is no programming, scripting or separate compiling needed. This ease of use combines with the capability to connect to any server and client in a network for unparalleled flexibility in process control. Lookout also features interactive Web access. True

online capability means that Lookout application development and modification are done without ever stopping the process.

Because Lookout executes objects in an event-driven manner it has been used extensively in networked, continuous, discrete, batch and telemetry system applications requiring high performance with every large point counts.

2.3.3 The Lookout Works

Lookout consists of objects and their data members and parameters, connections between objects, and services. Objects are software representations of everything from potentiometers and switches, to PLCs and RTUs connected physically to a computer running Lookout. To develop a Lookout process, you create, configure, and connect objects.

You can make connections between your computer and various PLCs or other controllers; between your computer and various sensors; between your computer and other computers; and between your computer and the Lookout database, Citadel. Lookout and the Lookout services handle these connections. You can use the Connection Browser to view existing connections.

Keep in mind that Lookout is entirely event-driven, not loop-driven. Loop-driven applications execute code from top to bottom, loop back, execute the same code over and over, and may execute millions of times before any result changes. This wastes computer processor time and slows down responses to frequent events.

An "event" is a change in a data value. When an incoming signal to an object changes, the object processes the value. And when the result of the object's processing changes, it sends out signals. In this way, an event propagates throughout your system, creating a chain reaction that affects only the objects that need to be involved.

2.4 Operating Procedure

- Connect up all the fieldbus devices.
- Connect the signal cable from the signal filter to the serial port of the NI card.
- Power up the PC and the Fieldbus devices.
- Click the NI fieldbus configurator icon to start.
- NI fieldbus configurator scans all the fieldbus device addresses and function blocks.
- Let NI fieldbus configurator finish scanning.
- Click the NI fieldbus LOOKOUT icon to start.
- Click file open.
- Open the project file.
- Software is ready at non-edit mode.
- Program ready for visual monitoring.

2.5 Data measurement and analysis

2.5.1 Healthy Valve Signature

What are the important features of a valve signature curve? Firstly observe the combine lines that appear on each end of the curve. This verifies that a solid stop had been reached at both ends of travel. This is very important, for without a visual indication that the stops were reached; one could not verify that full travel had been achieved, nor that the analyzed benchset is correct. Next, look to see that the opening (Red) and closing (blue) lines are parallel and linear throughout the full stroke. The separation of these links is the result of the friction band. The higher the friction the wider the separation. Because friction always opposes motion, the net spread of these lines is actually double the friction (friction opposing the up stroke plus friction opposing the down stroke).

In Figure 1, the blue line shows a health valve signature of a valve closing fully.

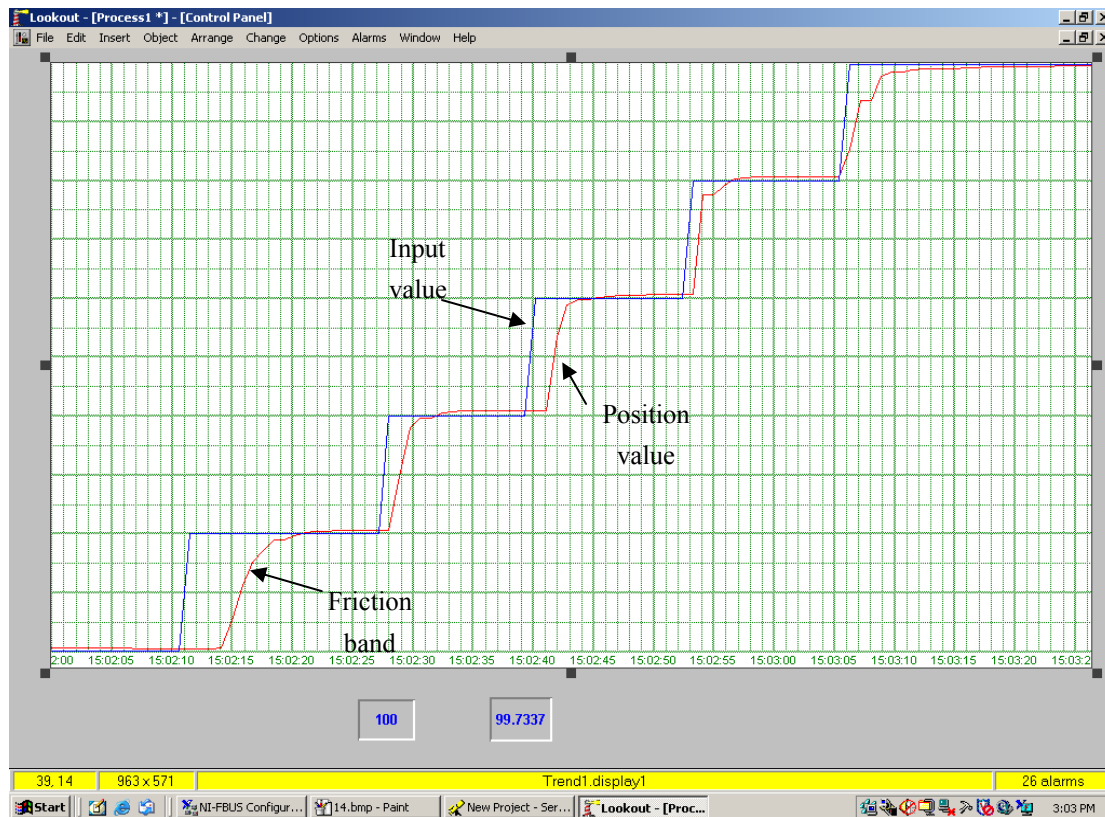


Figure 1 Healthy Valve Signature

2.5.2 Detecting various failures

The typical failures include being stuck in last position and not operating when needed. This could result in a dangerous condition leading to an explosion, fire, or a leak of lethal chemicals and gases into the environment. To ensure the needed reliability and availability of these safety shutdown valves, they need frequent testing.

Unfortunately, the traditional method of testing these safety valves does not provide any internal valve diagnostics. It just allows mechanical movement but does not specifically provide inputs such as: if the valve friction is increasing, process build up is occurring on bearing/shaft area, pressure is decaying; valve torque requirement is increasing, etc. One way to solve those issues is a digital valve controller. Their diagnostic capabilities can dramatically hike the reliability of these safety systems, and at the same time, reduce the risk of spurious trip, unscheduled maintenance, manual laborious test procedures, associated cost, as well as gaining a multitude of additional advantages.

a) Position Configuration

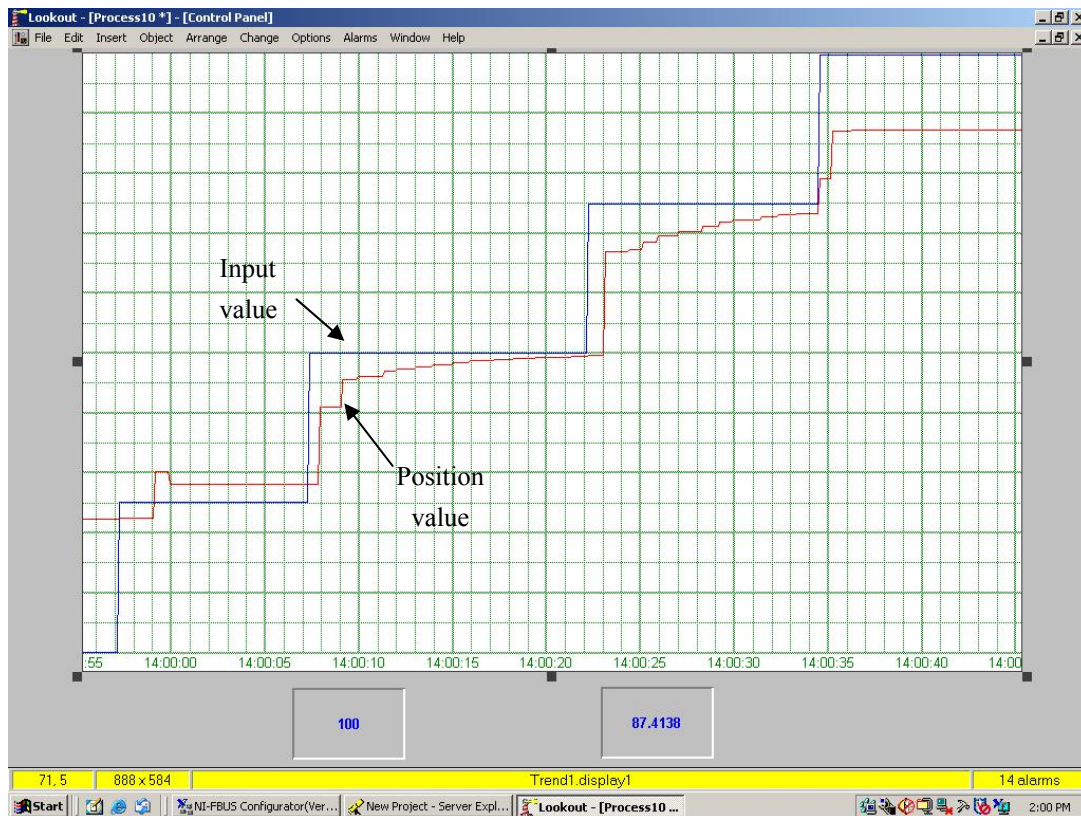


Figure2 valve signature of a valve not fully opening and closing

In Figure 2, it shows a valve signature of a valve not fully opening and closing. This is due to the valve need to make the calibration operation. It is necessary to match the source of reference applied to or connected to the device with the desired value. At least four parameters should be used to configure this process: CAL_POINT_HI, CAL_POINT_LO, CAL_MIN_SPAN, and CAL_UNIT. Those parameters define the highest and lowest calibrated values for this device, the minimum allowable span value for calibration (if necessary) and the engineering unit selected for calibration purposes.

b) Leaking air supply

Figure3 show the fault value signature vs. the health valve signature. It is because of that restrictions to the flow of air through either the solenoid valve, the exhaust/vent ports of the quick exhaust valve, or the actuator cause varying degrees of blockage and a number of different conditions that will ultimately affect system performance. Depending upon the degree of restriction/blockage, the effects could range between a

slowing of operation to prevention of closure. Figure 3 shows an example of a partially blocked quick exhaust valve vent port.

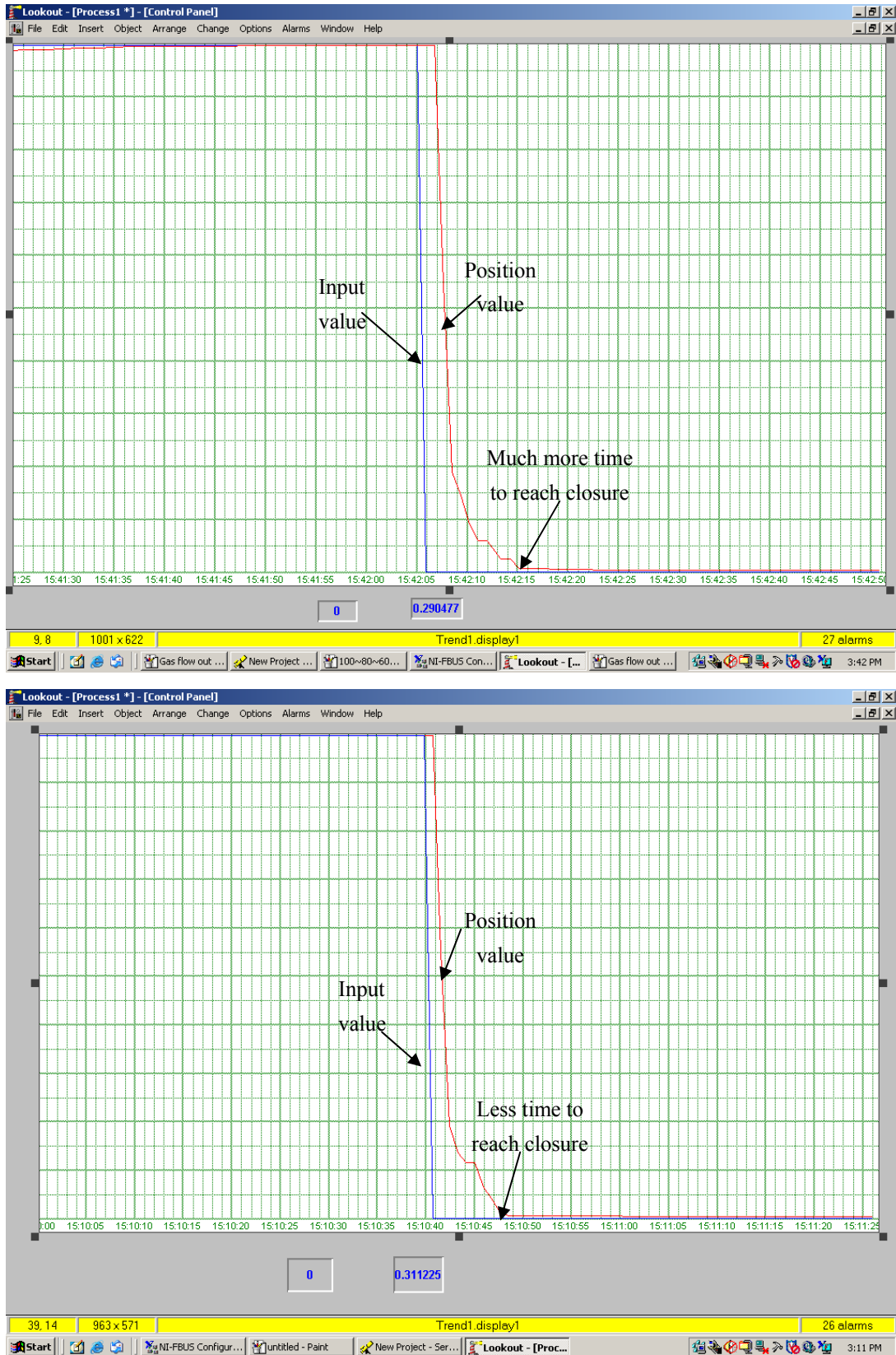
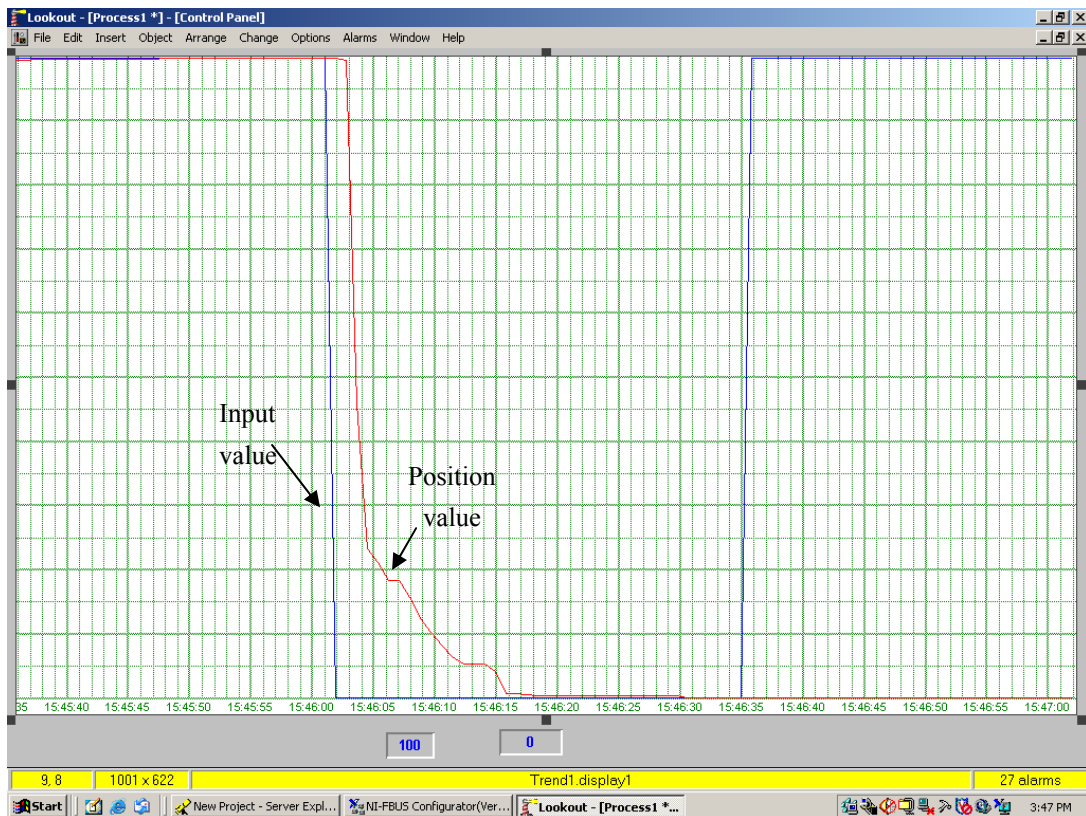


Figure3 fault value signature vs. the health valve signature

c) Coil breakdown



If the operation of the solenoid has slowed or unmoved due to wear or partial breakdown of its coil, the solenoid operation will be delayed or unrespond. An example of this impending failure is shown in Figure 4.

2.6 Valve diagnostic application advantages

Valve diagnostic application benefits end user a lot as described in the previous section. It can let the user know the status of the valve and know whether the valve needs any maintenance before it fails to operate properly. This application will give them convenience of knowing the valve status in advance saving them lots of time and money.

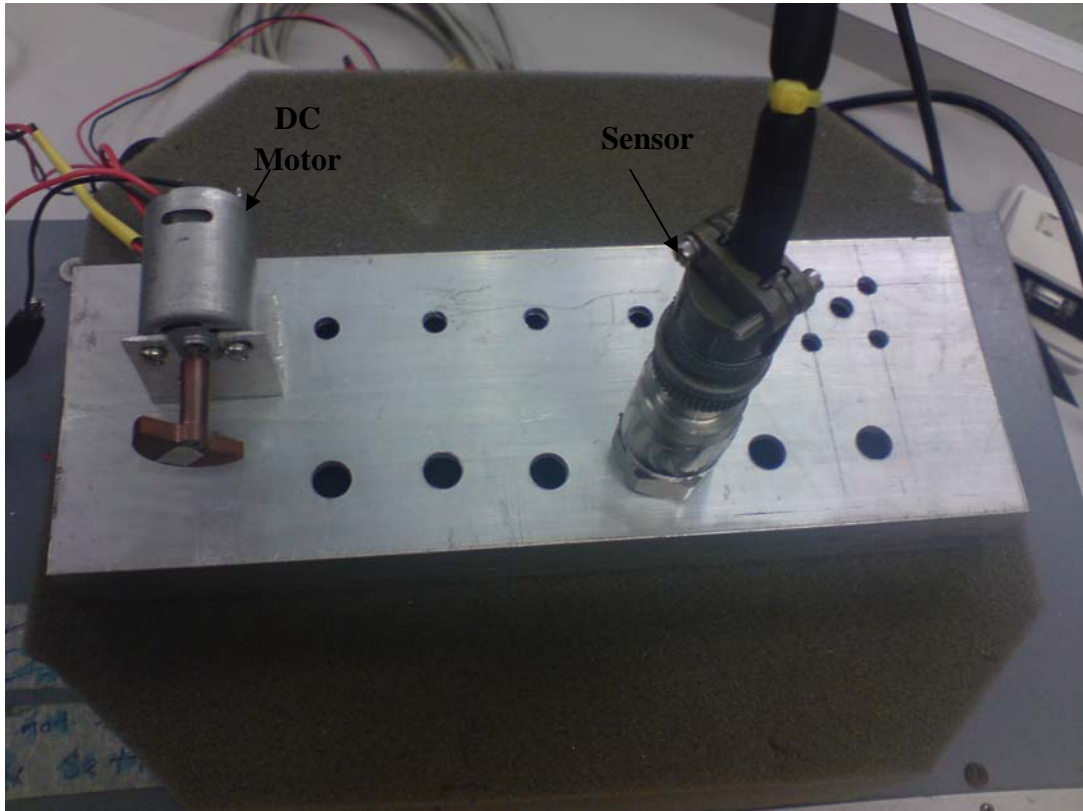
This method of partial stroking and valve signature can be used with any valve (e.g., linear / rotary, pneumatic / hydraulic), regardless of manufacturer. Retrofitting the pressure transmitter and microcomputer to an existing installation is a simple and inexpensive procedure. The testing can be performed automatically, faults can be

alarmed immediately and results recorded. In order to achieve the full benefit of signatures, however, installation with the new valve assembly at the factory is recommended.

Chapter 3

Signature Analysis method for Motors operating

3.1 DC Motor and Sensor



3.1.1 About Vibration Sensors

Vibration sensors are sensors for measuring, displaying and analyzing linear velocity, displacement and proximity, or else acceleration. They can be used on a stand-alone basis, or in conjunction with a data acquisition system. Vibration sensors are available in many forms. They can be raw sensing elements, packaged transducers, or as a sensor system or instrument, incorporating features such as totalizing, local or remote display and data recording.

Vibration sensors can have measurement with different axis, the multiple axes typically being orthogonal to each other. These devices work on many operating principles. The most common types of vibration sensors are piezoelectric, capacitance, null-balance, strain gage, resonance beam, piezoresistive and magnetic induction. An

alternative to traditional vibration sensors is one manufactured using MEMS technology, a micro-machining technology that allows for a much smaller device and thus package design.

Five main features must be considered when selecting vibration sensors: measuring range, frequency range, accuracy, transverse sensitivity and ambient conditions. Measuring range can be in G's for acceleration, in/sec for linear velocity (or other distance over time), and inches or other distance for displacement and proximity. Frequency is measured in Hz and accuracy is typically represented as a percentage of allowable error over the full measurement range of the device. Transverse sensitivity refers to the effect a force orthogonal to the one being measured can have on the reading. Again, this is represented as percentage of full scale of allowable interference. For the ambient conditions, such things as temperature should be considered, as well as the maximum shock and vibration the vibration sensors will be able to handle. This is the rating of how much abuse the device can stand before it stops performing, much different from how much vibration or acceleration vibration sensors can measure.

Electrical output options depend on the system being used with the vibration sensors. Common analog options are voltage, current or frequency. Digital output choices are the standard parallel and serial signals. Another option is to use vibration sensors with an output of a change in state of switches or alarms. In addition, these sensors can have acceleration, velocity, or displacement as output by either integrating or differentiating their primary output.

When mounting vibration sensors, many choices must be weighed based on application and ability. Probably the most secure method is stud mounting. Many vibration sensors have the option of a threaded section that can be fastened to the machinery or object being monitored. For applications where this is not possible or desirable, many other options are available: wax, magnets and adhesive. Some applications require vibration sensors to be mounted on an electrically isolated surface to provide ground isolation between the mounting surface and signals from the

vibration sensors. Triaxial mounting cubes can also be purchased to mount three vibration sensors together in an orthogonal configuration to each other. This way, only one mounting surface on the monitored device has to be used for all three.

3.1.2 Why Monitor Vibration?

Global competition and pressure on corporate performance makes productivity a primary concern for any business in the 90's. Machinery vibration monitoring programs are effective in reducing overall operating costs of industrial plants. Vibrations produced by industrial machinery are vital indicators of machinery health. Machinery monitoring programs record a machine's vibration history. Monitoring vibration levels over time allows the plant engineer to predict problems before serious damage occurs. Machinery damage and costly production delays caused by unforeseen machinery failure can be prevented. When pending problems are discovered early, the plant engineer has the opportunity to schedule maintenance and reduce downtime in a cost effective manner. Vibration analysis is used as a tool to determine machine condition and the specific cause and location of machinery problems. This expedites repairs and minimizes costs.

3.2 National Instruments USB-6009

The National Instruments USB-6009 provides basic data acquisition functionality for applications such as simple data logging, portable measurements, and academic lab experiments. The NI USB-6009 is a USB based data acquisition (DAQ) and control device with analog input and output and digital input and output. It is affordable for user use and powerful enough for more sophisticated measurement applications.

To supplement simulation, measurement, and automation theory courses with practical experiments, NI developed a USB-6009 Student Kit that includes a copy of the LabVIEW Student Edition. These kits are \giving them a powerful, low-cost, hands-on learning tool.

NI USB-6009 DAQ devices deliver multifunction capabilities with eight channels of 12- or 14-bit analog input, two analog outputs, 12 digital I/O lines and one counter. Both devices draw power from the USB bus, so they do not require an external power supply to operate. They include removable screw terminals for direct signal connectivity, an onboard voltage reference for powering external devices and sensors, a four-layer board design for reduced noise and improved accuracy and overvoltage protection on analog input lines up to 25 V. In addition to ready-to-run data-logging software, each device includes NI-DAQmx Base measurement services driver software for programming the device in LabVIEW or C.

3.2.1 The main features of NI USB-6009

- Analog input (AI): 8 inputs with referenced single ended signal coupling or 4 inputs with differential signal coupling. Software-configurable voltage ranges: $\pm 20\text{V}$, $\pm 10\text{V}$, $\pm 5\text{V}$, $\pm 4\text{V}$, $\pm 2.5\text{V}$, $\pm 2\text{V}$, $\pm 1.25\text{V}$, $\pm 1\text{V}$. Max sampling rate is 48kS/s (48000 samples per second). 14 bits AD converter (USB-6008: 12 bits).
- Analog output (AO): 2 outputs. Voltage range is 0 - 5V (fixed). Output rate is 150Hz (samples/second). 12 bits DA converter.
- Digital input (DI) and digital output (DO): 12 channels which can be used as either DI or DO (configured individually). These 12 channels are organized in ports, with Port 0 having lines 0, ..., 7, and Port 1 having lines 0, ..., 3. Input low is between -0.3V and +0.8V. Input high is between 2.0V and +5.8V. Output low is below 0.8V. Output high is above 2V (with open-drain and push-pull as options). (USB-6008 has only open-drain output.)
- Counter: 32 bits. Counting on falling edge.
- On-board voltage sources (available at individual terminals): 2.5V and 5.0V
- Power: USB-6009 is powered via the USB cable.
- Configuring and testing: USB-6009 can be configured and tested using

- Application software: LabVIEW, C, or Visual Studio. Platforms: Windows, Mac, Linux. The present document gives an example of how to use USB-6009 in LabVIEW.

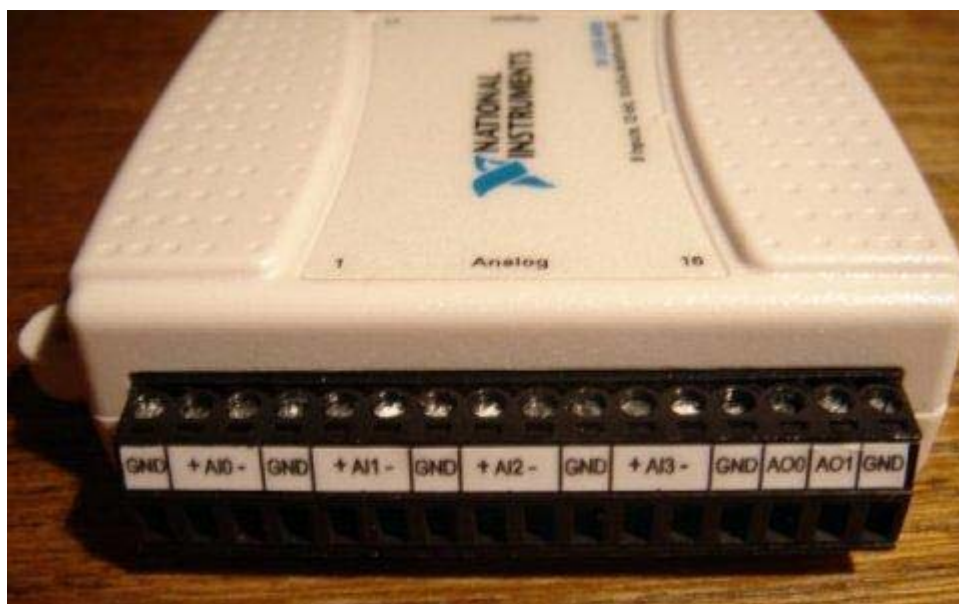
3.2.2 Benefits of NI-DAQ Drive

- Improved Ease of Use
- Faster Performance
- Increased Engineering Efficiency
- Measurement Multithreading

3.3 NI USB-6009 Setting up Procedure

3.3.1 Label the I/O terminals

Before start using the USB-6009, it should attach labels to the analog and digital terminals. Below figure shows the *analog* I/O terminals with labels assuming differential signal coupling. (In general, differential signal coupling is preferable to single ended coupling due to better DC noise suppression).



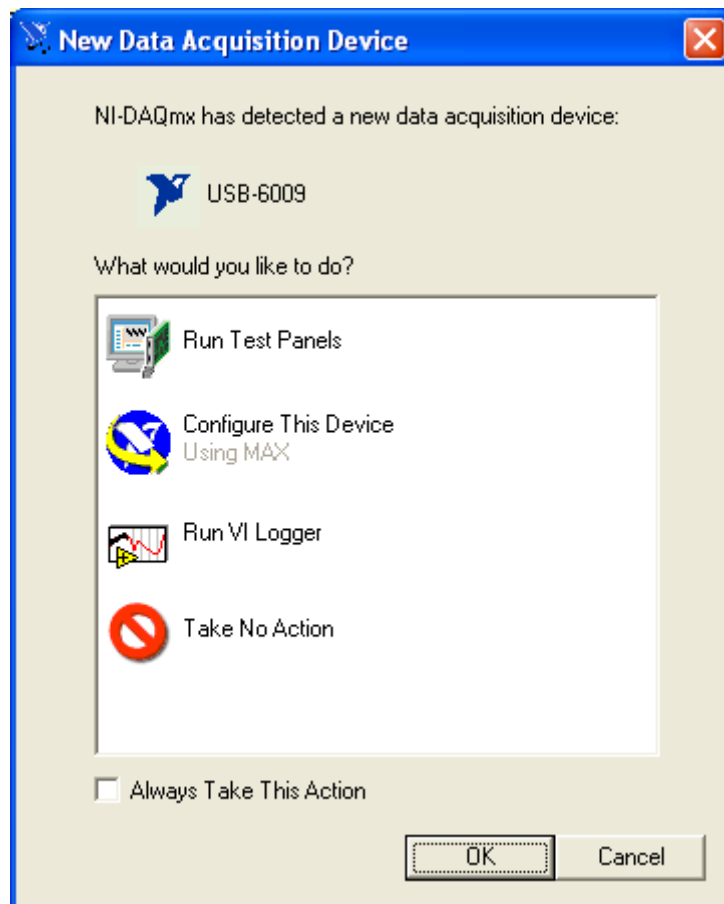
The analog I/O terminals with labels assuming differential signal coupling

3.3.2 Connecting USB-6009 to the PC

When connect the USB-6009 to the PC in first time, the Windows Hardware Installer Wizard will open. Then, the wizard searches the PC for the necessary driver software for the USB-6009. This driver software was installed along with the installation of the NI-DAQ software.

When the wizard has finished the installation of the driver software, the USB-6009 is ready for use.

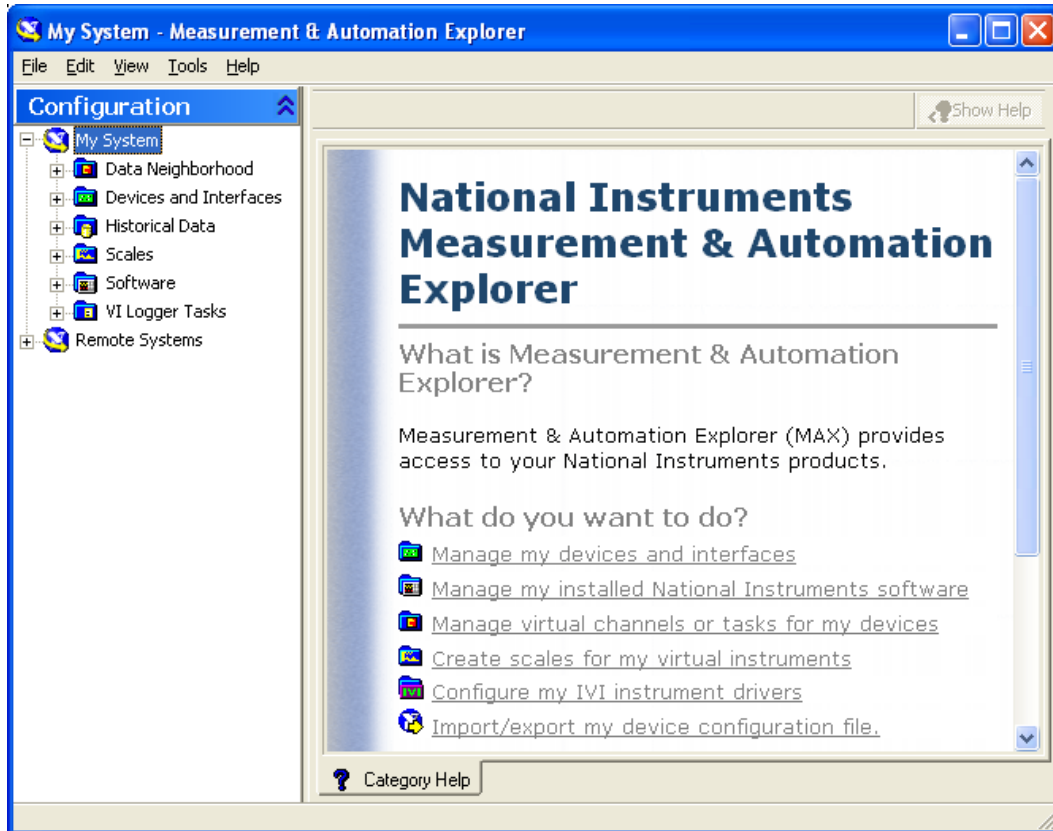
next disconnect the USB-6009 from the PC, and then re-connect it later, the **New Data Acquisition Device** dialog window pops up, giving some several options as per below Figure.



The New Data Acquisition Device dialog window

3.3.3 Testing USB-6009 in MAX (Measurement & Automation Explorer)

Before start to use the USB-6008 in an application, it should test the device in the MAX utility, which is via **Start / Programs / National Instruments**. Blow figure shows MAX.



MAX (Measurement and Automation Explorer)

In the MAX window, expand the Devices and Interfaces item, see Figure as below.

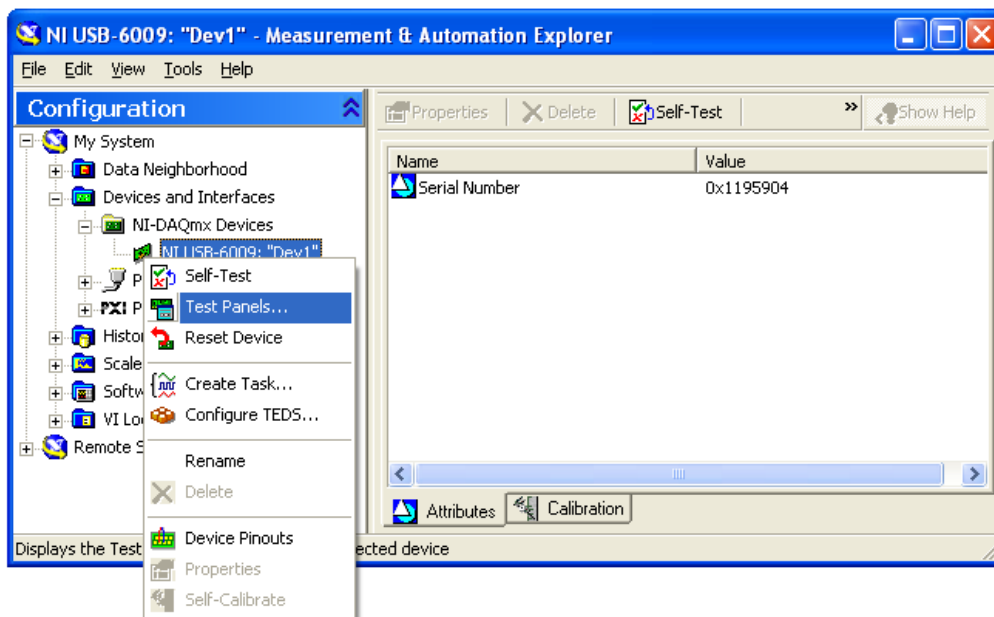


Figure1. The Devices and Interfaces item

If MAX recognizes the USB-6009, the device appears under NI-DAQmx Devices. It should test the individual channels of the USB-6009 to check that the input signals are detected correctly by the USB-6009, and that the output signals generated by the USB-6009 have correct values. This I/O can be tested in several ways, depending on which channels actually want to test. Here, test analog output channel 0 (AO0) and the analog input channel 0 (AI0) to see if they work correctly. a very simple test, which is sufficient if we are to check that both AO0 and AI0 work correctly. The test procedure, which is denoted *loopback*, is to connect the AI0 channel to the AO0 channel. Then generate some legal voltage at AO0. If AI0 detects the same voltage, it will know that both AO0 and AI0 works. (It also may then repeat this procedure for other channels.) If for some reason AI0 detects some other voltage than the value which is set for AO0, then there is an error in either the AI0 channel or in the the AO0 channel, and further investigations are necessary.

To prepare for the loopback test, wire together AI0 and AO0. To see the terminals of the USB-6009, select Device Pinouts in the menu shown in upon Figure. Then terminals or pins are shown in the NI-DAQmx Device Terminals window.

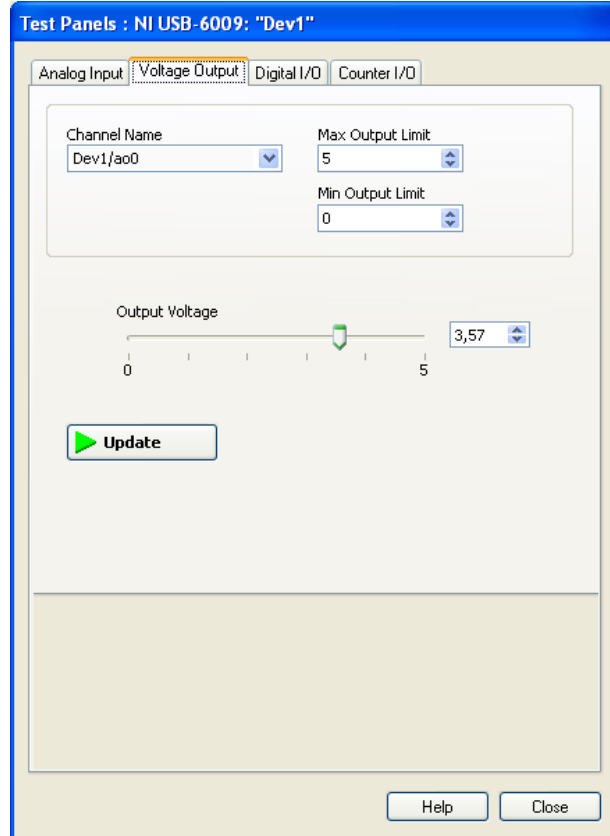
NI USB-6009			
GND	1	17	P0.0
AI 0/AI 0+	2	18	P0.1
AI 4/AI 0-	3	19	P0.2
GND	4	20	P0.3
AI 1/AI 1+	5	21	P0.4
AI 5/AI 1-	6	22	P0.5
GND	7	23	P0.6
AI 2/AI 2+	8	24	P0.7
AI 6/AI 2-	9	25	P1.0
GND	10	26	P1.1
AI 3/AI 3+	11	27	P1.2
AI 7/AI 3-	12	28	P1.3
GND	13	29	PFI 0
AO 0	14	30	+2.5 V
AO 1	15	31	+5 V
GND	16	32	GND

The terminals or pins are shown in the NI-DAQmx Device Terminals window



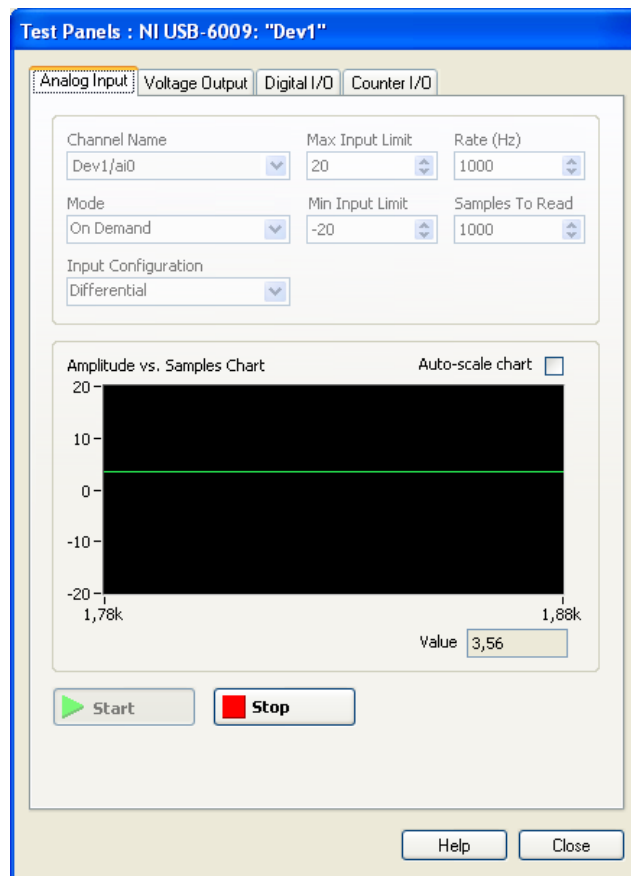
To prepare for the loopback test, AI0 and AO0 are wired together.

To actually perform the loopback test, right-click on the device labeled **NI USB-6009: "Dev1"** in MAX, and then select **Test Panels**, thereby opening the Test Panels. In the Test Panels window, select the Voltage Output tab, see below figure.



The Voltage Output dialog window in the Test Panels window

In the **Voltage Output dialog window**, select any voltage between 0V and 5V. In upon Figure, an output voltage of 3.57V is set. Next, click the **Analog Input tab** in the **Test Panels window**, see below Figure. Un-tick Auto-scale chart in the window.



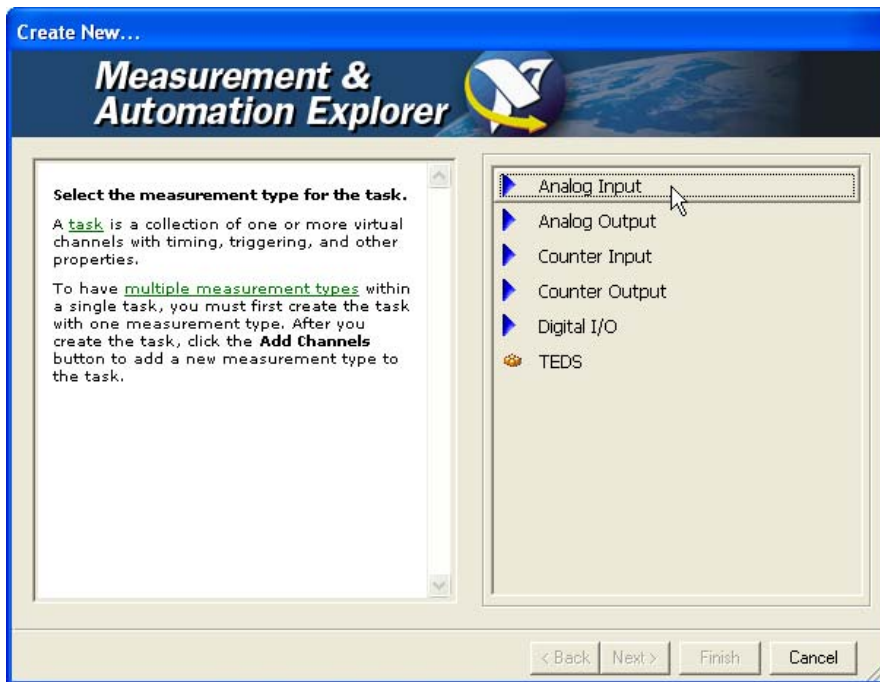
If the channel testing passed without problems, you may end the testing session by setting 0V on the output (in the Voltage Output window).

3.3.4 Configuring the USB-6009 in MAX

After the above testing has passed successfully, next it must configure the USB-6009 in MAX. In the following create *tasks* for the analog input and the analog output operations. These tasks are referred to in the application program, e.g. LabVIEW. In general, a task represents the configuration of the signal input or signal output operation to be executed by the I/O device. Creating tasks is a general feature of the MAX utility.

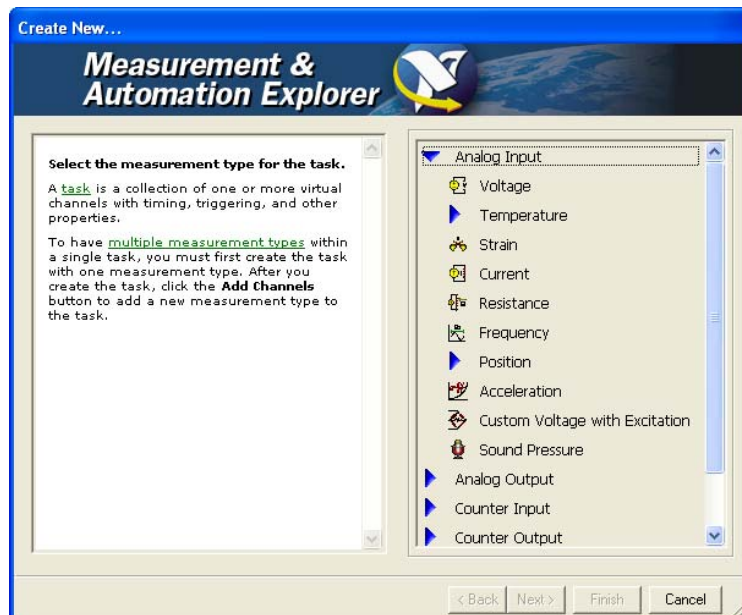
3.3.5 Configuration of an analog input task

From Figure1, Selecting **Create Task** in the menu opens a window where it can select the measurement type, see Figure in below.



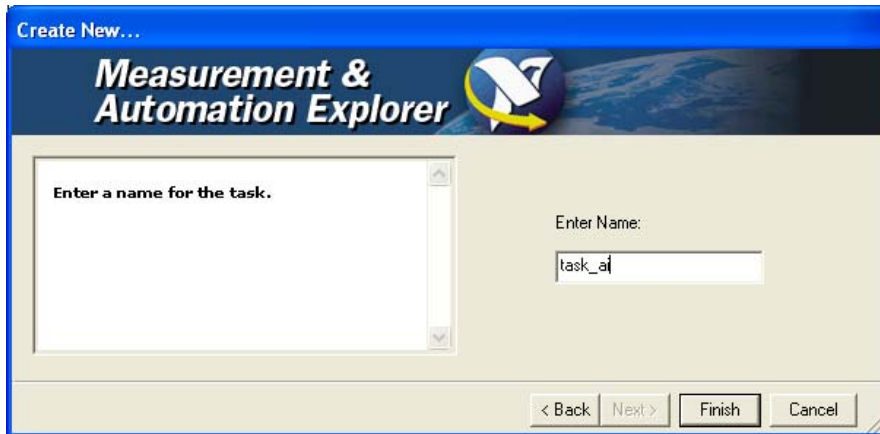
Window where you select the measurement type

Select **Analog Input** and opens the window shown in below Figure where it can select the measurement type from a list.



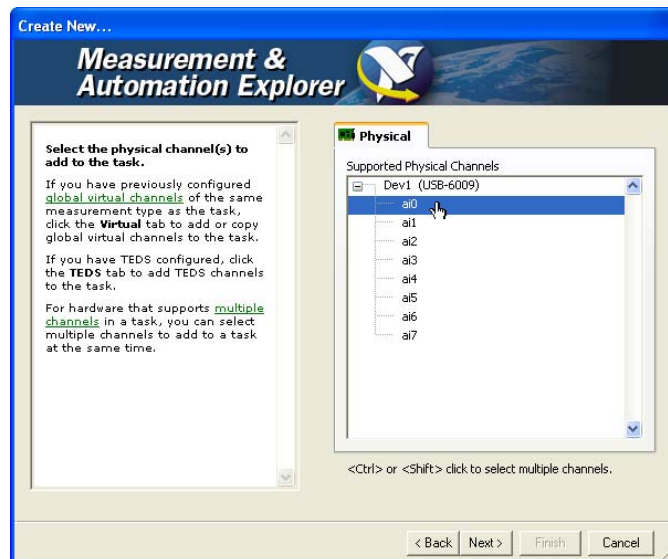
A list of options for the measurement type

From the list of measurements type, select **Voltage** for this experiment, which opens the window shown in below Figure where enter the name of the task.



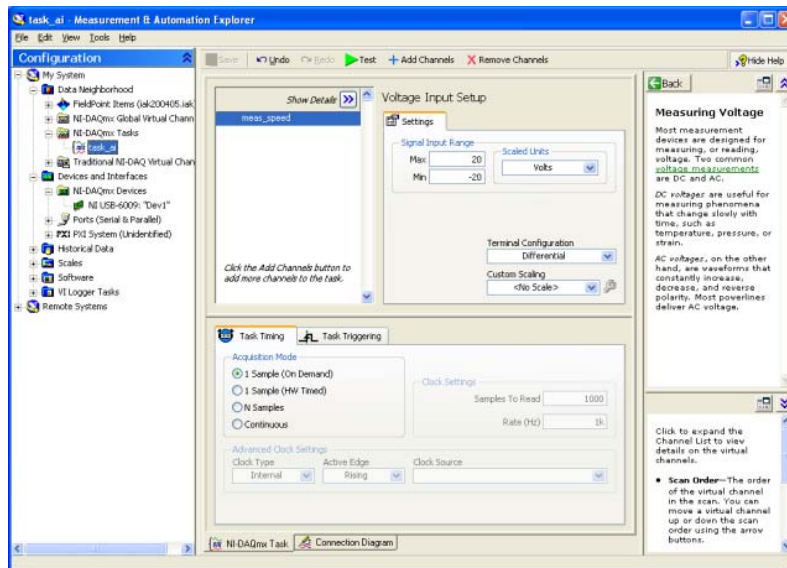
Window where you can enter the name of the task

By clicking the **Finish** button in the window shown in upon figure, the window shown in below following figure is opened where it can select the physical channels.



Selecting physical channel for the task

In the window shown in upon figure select **ai0**, which opens the window shown as below.



Window for configuration of the analog input associated with task_ai0

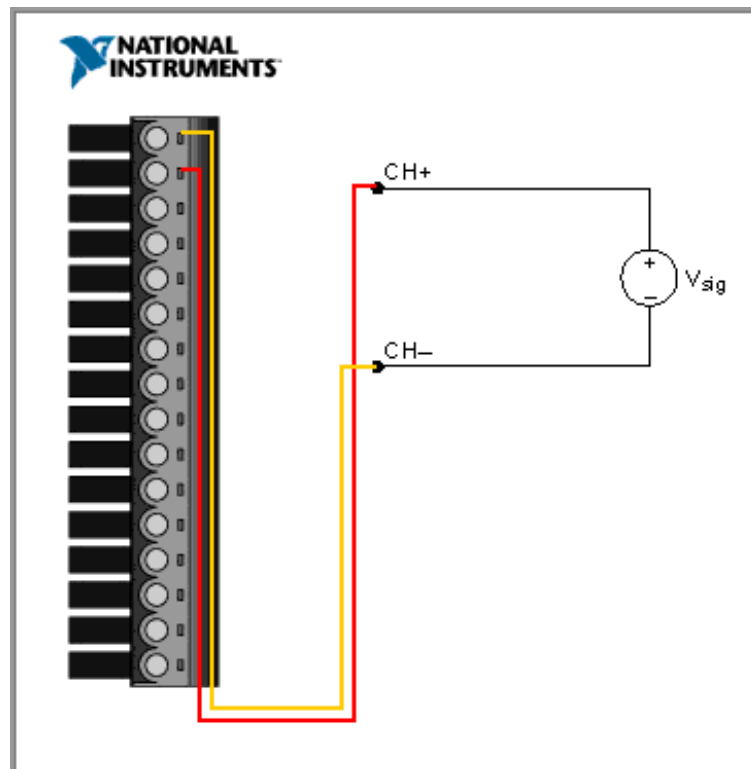
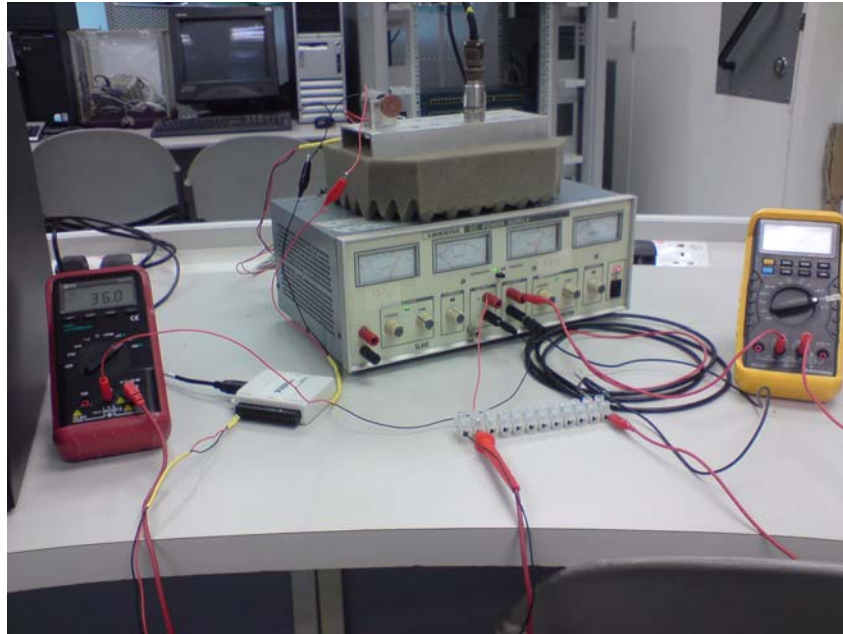
3.4 Operation Procedure

For this pilot study, the connections for all devices as show in below figure. To verify the theoretical concept, it was carried out simple testing equipment using National Instrument USB-6009 and the testing of the motor was set on a base with a sensor. Measure the both of current by using Multimeter. By using a dual DC power supply to provide the dc voltage which the output voltage can be adjusted from zero (0) to a maximum value 30.

To connect each of device to the NI USB-6009, 250Ω of Resistor is used. This resistor is used to convert the current to voltage. Below figure display the connection for this experiment.

- Connect the output of the accelerometer amplifier to the Multimeter.
- Connect the output of the motor to the Multimeter and the NI USB-6009 device.
- Connect the motor and accelerometer to the DC power supply. Set the supply to 24v.
- Attach the accelerometer to the top of the encoder wheel post
- Power on the motor and observe the reading on both NI USB-6009 software and the Multimeter.

- Power down the motor, and replace the existing encoder wheel with the weighted encoder wheel (half load & full load). After attaching the new wheel, power up the motor again and view the output on the Multimeter and NI USB-6009.
- Similarly, measure the sensor output by connects it to the NI USB-6009 and record the output on the Multimeter and NI USB-6009.



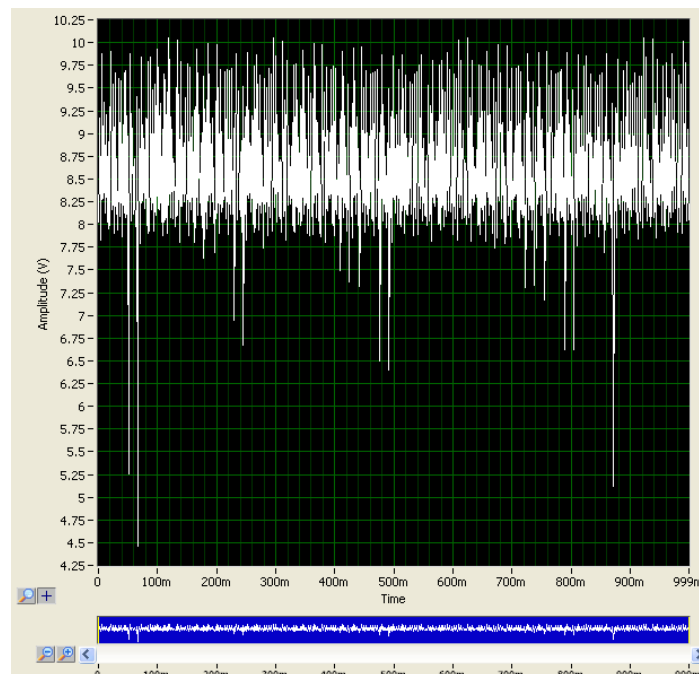
3.5 Data measurement and analysis

The next step is to look at the data and see if any regularity can be noted under different load and fault conditions. The data is generated for three different load conditions: vibration produced with quarter load, half load and full load. The load is determined with respect to the nominal load present in the motor nameplate. The voltages used to feed the motor are obtained from a DC power supply.

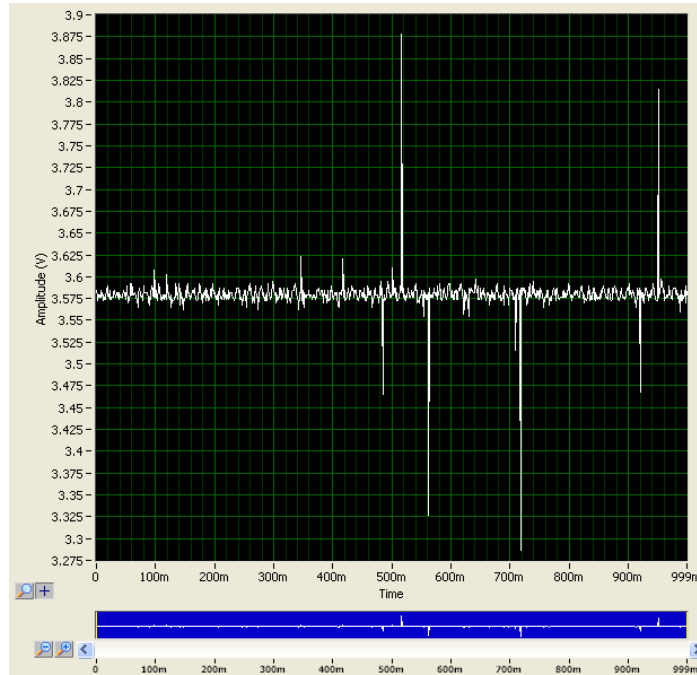
a) Vibration produced with Quarter load.



Quarter load device

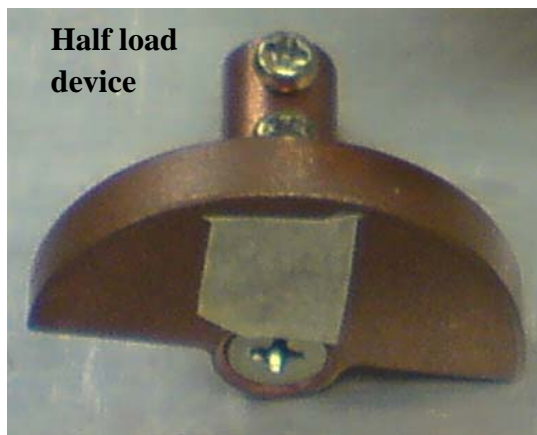


Motor vibration Amplitude (V) with quarter load

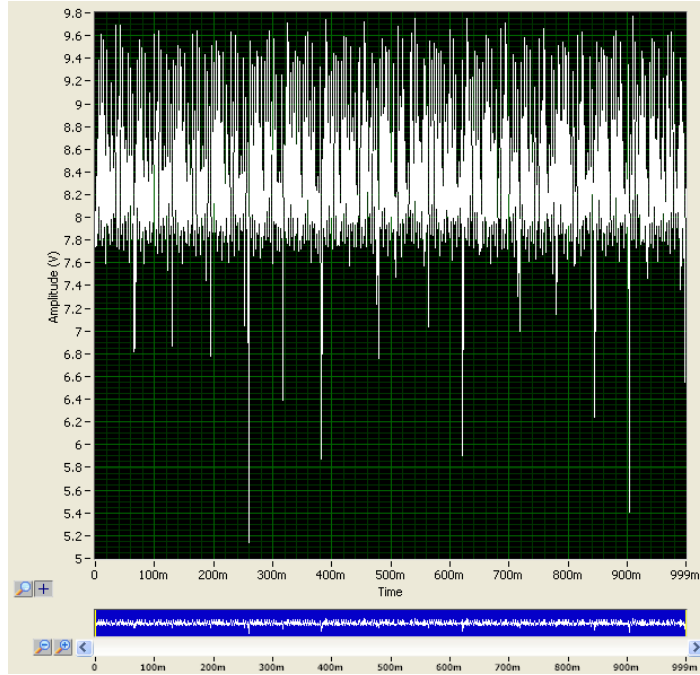


Sensor vibration Amplitude (V) with quarter load

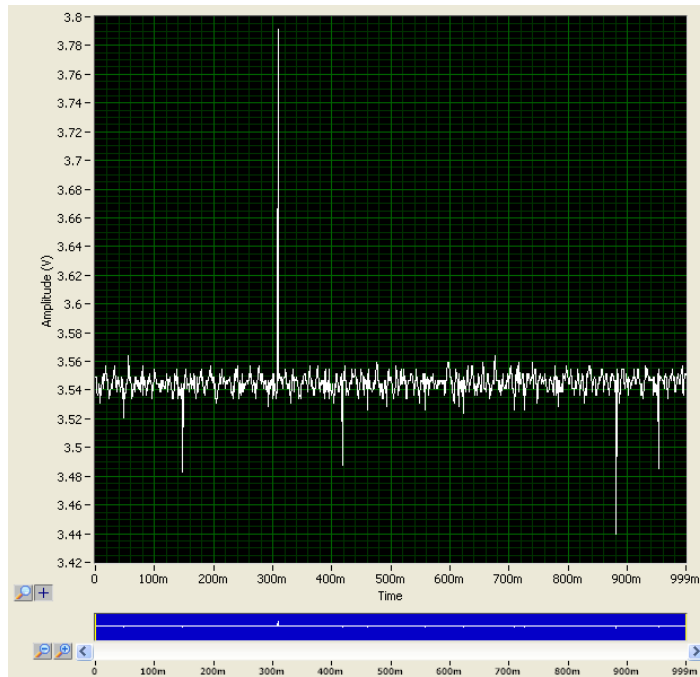
b) Vibration produced with half load



Half load device

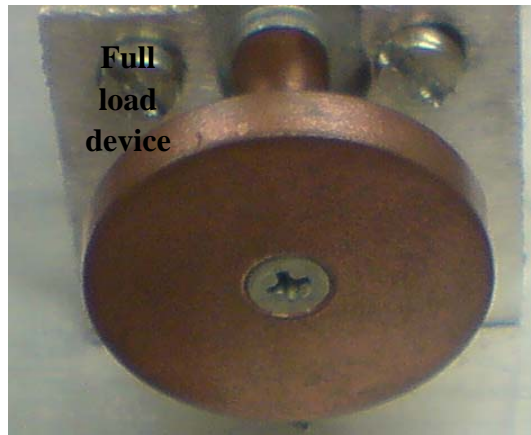


Motor vibration Amplitude (V) with half load

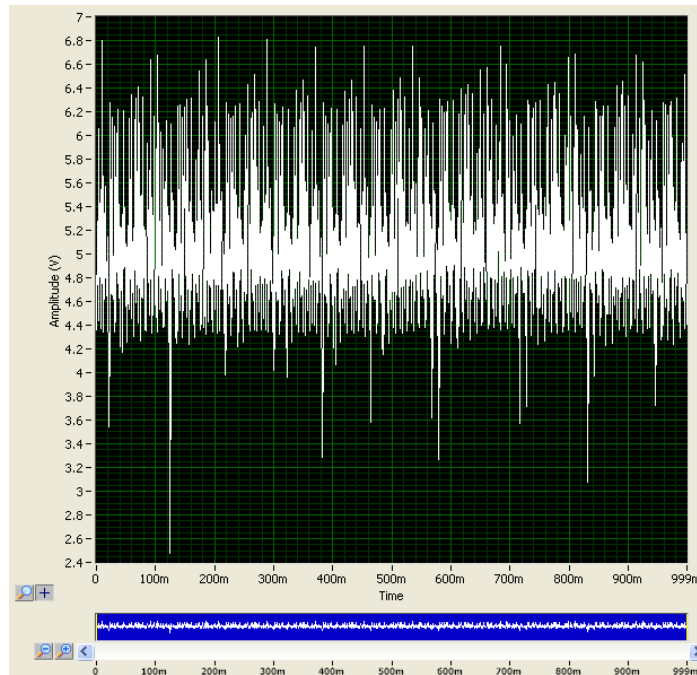


Sensor vibration Amplitude (V) with half load

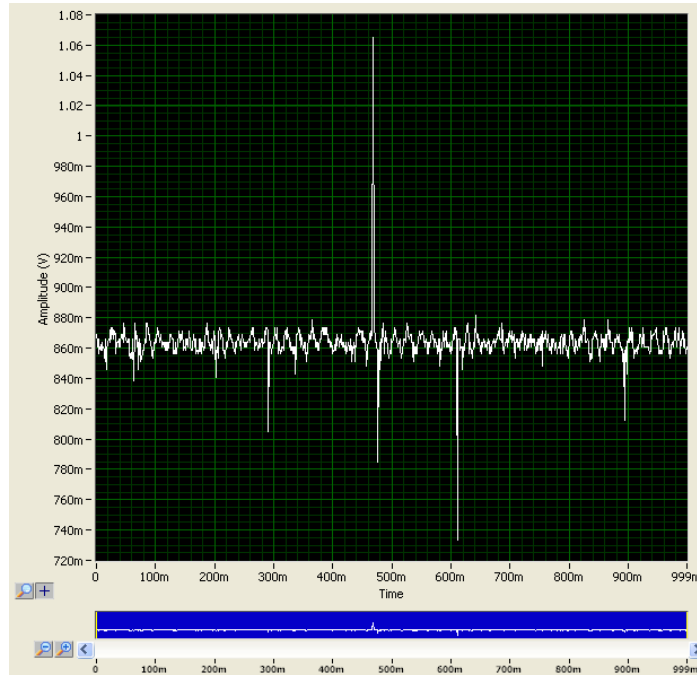
c) Vibration produced with full load



Full load device



Motor vibration Amplitude (V) with full load



Sensor vibration (V) with full load

The figures above show the Amplitude (V) when a healthy motor is under different load conditions. The second and third figure is the sensor's Amplitude (V) and current (*i*) respond under different load situation. The figures show clearly that the amplitude of the motor and sensor decrease as the load increases. In no-load condition the amplitude of motor and sensor are around 8.75v and 3.575v, for half a load 8.4v and 3.54v, for full load 5v and 0.86v, and the current of sensor is 82.7mA~83.5mA, 82.6mA~83.4mA, 82.6mA~83.3mA. Approximately, the figures also indicate that the form of the amplitude of motor and sensor changes with respect to load. Hence it is suitable to model the different load conditions separately.

The results show that a DC rotor fault cannot be diagnosed properly under vibration produced with no-load and half-load operation. The fault diagnosis system can not make a distinction between the DC rotors.

CHAPTER 4

Conclusions and Recommendations

Based on the results have been obtained and studying the interoperability of Foundation Fieldbus devices with the control valve, the vibration diagnosis of DC motor by using the National Instrument. I can conclude that the project complete in both portion, has achieved most of the objectives. These objectives include getting and sending information to and from the different fault valve with different conditions, and developed use of NI USB-6009 for fault diagnostics of DC motor. The idea was to use data provided by accurate simulation of motor operation under different load condition.

Developing a valve diagnostic application may be easily carried out by using Lookout. This project study provides a useful example to use NI Lookout Software but still keen to use fieldbus data for diagnostic purpose. Using technology such as Lookout allows us to develop interoperable valve diagnostics applications very easily.

In conclusion, this project allows me to understand how to make use of National Instrument software and also understanding the function Foundation fieldbus. This final year project has improved my troubleshooting skill and a better understanding on Foundation fieldbus technology and National Instrument software is achieved as well. Also from this project I had gained a great deal of experience in manufacturing industries areas such as electrical and control engineering.

CHAPTER 5

Reference

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