

Introduction to Data Acquisition

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Overview

This tutorial is part of the National Instruments Measurement Fundamentals series. Each tutorial in this series teaches you a specific topic of common measurement applications by explaining the theory and giving practical examples. This tutorial gives an introduction to the basic elements of a computer-based data acquisition system.

For the complete list of tutorials, return to the NI Measurement Fundamentals main page (<http://www.ni.com/white-paper/4523/en/>).

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1. Introduction

Data acquisition involves gathering signals from measurement sources and digitizing the signals for storage, analysis, and presentation on a PC. Data acquisition systems come in many different PC technology forms to offer flexibility when choosing your system. You can choose from PCI, PXI, PCI Express, PXI Express, PCMCIA, USB, wireless, and Ethernet data acquisition for test, measurement, and automation applications. Consider the following five components when building a basic data acquisition system (Figure 1):

- Transducers and sensors
- Signals
- Signal conditioning
- DAQ hardware
- Driver and application software

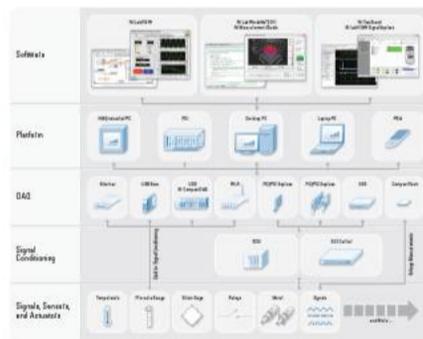


Figure 1. Data Acquisition System

2. Transducers

Data acquisition begins with the physical phenomenon to be measured. This physical phenomenon could be the temperature of a room, the intensity of a light source, the pressure inside a chamber, the force applied to an object, or many other things. An effective data acquisition system can measure all of these different phenomena.

A transducer is a device that converts a physical phenomenon into a measurable electrical signal, such as voltage or current. The ability of a data acquisition system to measure different phenomena depends on the transducers to convert the physical phenomena into signals measurable by the data acquisition hardware. Transducers are synonymous with sensors in data acquisition systems. There are specific transducers for many different applications, such as measuring temperature, pressure, or fluid flow. Table 1 shows a short list of some common phenomena and the transducers used to measure them.

Phenomenon	Transducer
Temperature	Thermocouple, RTD, Thermistor
Light	Photo Sensor
Sound	Microphone
Force and Pressure	Strain Gage Piezoelectric Transducer
Position and Displacement	Potentiometer, LVDT, Optical Encoder
Acceleration	Accelerometer
pH	pH Electrode

Table 1. Phenomena and Existing Transducers

Different transducers have different requirements for converting phenomena into a measurable signal. Some transducers may require excitation in the form of voltage or current. Other transducers may require additional components and even resistive networks to produce a signal. Visit [Sensors](http://sine.ni.com/nips/cds/view/p/lang/en/nid/10336) (<http://sine.ni.com/nips/cds/view/p/lang/en/nid/10336>) for more information on transducers.

3. Signals

The appropriate transducers convert physical phenomena into measurable signals. However, different signals need to be measured in different ways. For this reason, it is important to understand the different types of signals and their corresponding attributes. Signals can be categorized into two groups:

- Analog
- Digital

Analog Signals

An analog signal can exist at any value with respect to time. A few examples of analog signals include voltage, temperature, pressure, sound, and load. The three primary characteristics of an analog signal are level, shape, and frequency (Figure 2).

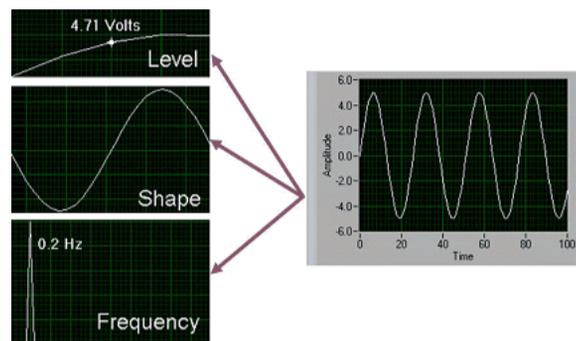


Figure 2. Primary Characteristics of an Analog Signal

Level

Because analog signals can take on any value, the level gives vital information about the measured analog signal. The intensity of a light source, the temperature in a room, and the pressure inside a chamber are all examples that demonstrate the importance of the level of a signal. When you measure the level of a signal, the signal generally does not change quickly with respect to time. The accuracy of the measurement, however, is very important. You should choose a data acquisition system that yields maximum accuracy to help with analog level measurements.

Shape

Some signals are named after their specific shapes - sine, square, sawtooth, and triangle. The shape of an analog signal can be as important as the level because by measuring the shape of an analog signal, you can further analyze the signal, including peak values, DC values, and slope. Signals where shape is of interest generally change rapidly with respect to time, but system accuracy is still important. The analysis of heartbeats, video signals, sounds, vibrations, and circuit responses are some applications involving shape measurements.

Frequency

All analog signals can be categorized by their frequencies. Unlike the level or shape of the signal, you cannot directly measure frequency. You must analyze the signal using software to determine the frequency information. This analysis is usually done using an algorithm known as the Fourier transform (<http://www.ni.com/support/labview/toolkits/analysis/analy3.htm>).

When frequency is the most important piece of information, you need to consider including both accuracy and acquisition speed. Although the acquisition speed for acquiring the frequency of a signal is less than the speed required for obtaining the shape of a signal, you still must acquire the signal fast enough that you do not lose the pertinent information while acquiring the analog signal. The condition that stipulates this speed is known as the Nyquist Sampling Theorem. Speech analysis, telecommunication, and earthquake analysis are some examples of common applications where the frequency of the signal must be known.

Digital Signals

A digital signal cannot take on any value with respect to time. Instead, a digital signal has two possible levels: high and low. Digital signals generally conform to certain specifications that define the characteristics of the signal. They are commonly referred to as transistor-to-transistor logic (TTL). TTL specifications indicate a digital signal to be low when the level falls within 0 to 0.8 V, and the signal is high between 2 and 5 V. The useful information that you can measure from a digital signal includes the state and the rate (Figure 3).

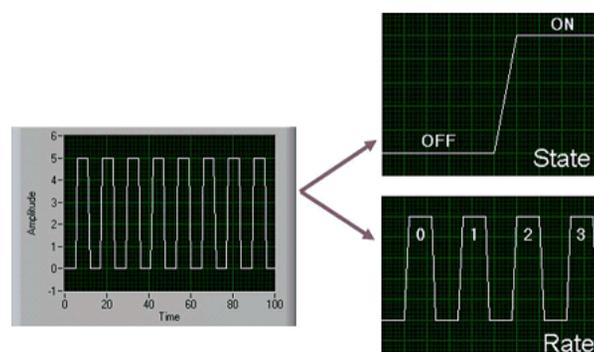


Figure 3. Primary Characteristics of a Digital Signal

State

Digital signals cannot take on any value with respect to time. The state of a digital signal is essentially the level of the signal - on or off, high or low. Monitoring the state of a switch - open or closed - is a common application showing the importance of knowing the state of a digital signal.

Rate

The rate of a digital signal defines how the digital signal changes state with respect to time. An example of measuring the rate of a digital signal includes determining how fast a motor shaft spins. Unlike frequency, the rate of a digital signal measures how often a portion of a signal occurs. A software algorithm is not required to determine the rate of a signal.

4. Signal Conditioning

Sometimes transducers generate signals too difficult or too dangerous to measure directly with a data acquisition device. For instance, when dealing with high voltages, noisy environments, extreme high and low signals, or simultaneous signal measurement, signal conditioning is essential for an effective data acquisition system. It maximizes the accuracy of a system, allows sensors to operate properly, and guarantees safety.

It is important to select the right hardware for signal conditioning. You can choose from both modular and integrated hardware options (Figure 4) and use signal conditioning accessories in a variety of applications including the following:

- Amplification
- Attenuation
- Isolation
- Bridge completion
- Simultaneous sampling
- Sensor excitation
- Multiplexing

Other important criteria to consider with signal conditioning include packaging (modular versus integrated), performance, I/O count, advanced features, and cost. Use online tools at [ni.com/signalconditioning](http://www.ni.com/signalconditioning) (<http://www.ni.com/signalconditioning>) to configure the best signal conditioning solution for your application.



Figure 4. Signal Conditioning Hardware Options

5. Data Acquisition Hardware

Data acquisition hardware acts as the interface between the computer and the outside world. It primarily functions as a device that digitizes incoming analog signals so that the computer can interpret them. Other data acquisition functionality includes the following:

- Analog input/output
- Digital input/output
- Counter/timers
- **Multifunction** (<http://www.ni.com/data-acquisition/multifunction/>) - a combination of analog, digital, and counter operations on a single device

National Instruments offers several hardware platforms for data acquisition. The most readily available platform is the desktop computer. NI provides PCI DAQ boards that plug into any desktop computer. In addition, NI makes DAQ modules for PXI/CompactPCI, a more rugged modular computer platform specifically for measurement and automation applications. For distributed measurements, the NI Compact FieldPoint platform delivers modular I/O, embedded operation, and Ethernet communication. For portable or handheld measurements, National Instruments DAQ devices for USB and PCMCIA work with laptops or Windows Mobile PDAs (Figure 5). In addition, National Instruments has launched DAQ devices for PCI Express, the next-generation PC I/O bus, and for PXI Express, the high-performance PXI bus. (<http://www.ni.com/data-acquisition/>)

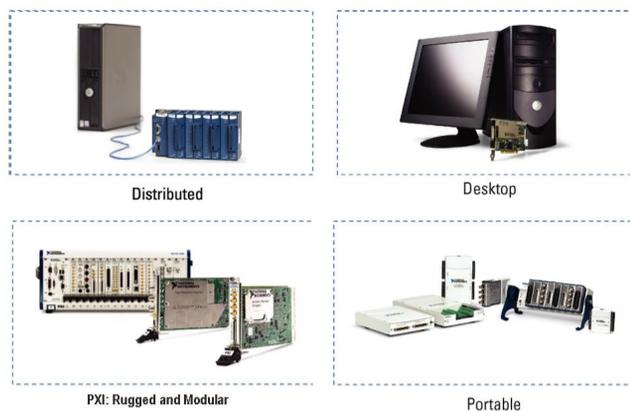


Figure 5. National Instruments DAQ Hardware Options

The newest DAQ devices from National Instruments offer connectivity over wireless and cabled Ethernet. NI Wi-Fi DAQ devices combine IEEE 802.11g wireless or Ethernet communication, direct sensor connectivity, and the flexibility of NI LabVIEW software for remote monitoring of electrical, physical, mechanical, and acoustical signals.

View Getting Started with Wireless NI CompactDAQ Chassis (<http://www.ni.com/video/2382/en/>)



Figure 6. Wi-Fi Data Acquisition

6. Driver and Application Software

Driver Software (<http://www.ni.com/dataacquisition/software/>)

Software transforms the PC and the data acquisition hardware into a complete data acquisition, analysis, and presentation tool. Without software to control or drive the hardware, the data acquisition device does not work properly. Driver software is the layer of software for easily communicating with the hardware. It forms the middle layer between the application software and the hardware. Driver software also prevents a programmer from having to do register-level programming or complicated commands to access the hardware functions. NI offers two different software options:

- [NI-DAQmx driver and additional measurement services software](http://sine.ni.com/nips/cds/view/p/lang/en/nid/10181) (<http://sine.ni.com/nips/cds/view/p/lang/en/nid/10181>)

With the introduction of NI-DAQmx, National Instruments revolutionized data acquisition application development by greatly increasing the speed at which you can move from building a program to deploying a high-performance measurement application. The DAQ Assistant, included with NI-DAQmx, is a graphical, interactive guide for configuring, testing, and acquiring measurement data. With a single click, you can even generate code based on your configuration, making it easier and faster to develop complex operations. Because the DAQ Assistant is completely menu-driven, you make fewer programming errors and drastically decrease the time from setting up your data acquisition system to taking your first measurement.

NI-DAQmx is available for Windows and Linux distributions. NI-DAQmx on Linux® only supports PCI, PCIe, PXI and PXIe hardware. For OSX support and USB or CompactDAQ support on Linux® please consider the NI-DAQmx Base driver. To investigate specific device support read the readme of the specific driver version, or reference this page <http://www.ni.com/product-documentation/6909/en/> (<http://www.ni.com/product-documentation/6909/en/>).

Application Software (<http://www.ni.com/software/>)

The application layer can be either a development environment in which you build a custom application that meets specific criteria, or it can be a configuration-based program with preset functionality. Application software adds analysis and presentation capabilities to driver software. To choose the right application software, evaluate the complexity of the application, the availability of configuration-based software that fits the application, and the amount of time available to develop the application. If the application is complex or there is no existing program, use a development environment.

NI offers three development environment software products for creating complete instrumentation, acquisition, and control applications:

- [LabVIEW](http://www.ni.com/labview/) (<http://www.ni.com/labview/>) with graphical programming methodology
- [LabWindows™/CVI](http://www.ni.com/cvi/) (<http://www.ni.com/cvi/>) for traditional C programmers
- [Measurement Studio](http://www.ni.com/mstudio/) (<http://www.ni.com/mstudio/>) for Visual Basic, C++, and .NET

With [DAQExpress](http://www.ni.com/en-us/shop/daqexpress.html) (<http://www.ni.com/en-us/shop/daqexpress.html>), NI has introduced a configuration-based software environment where programming is no longer a requirement. Using DAQExpress, you can make interactive measurements with NI Express technology.

7. More Information

Customers interested in this topic were also interested in:

- [LabVIEW](http://www.ni.com/labview/) (<http://www.ni.com/labview/>)
- [Data Acquisition](http://www.ni.com/data-acquisition) (<http://www.ni.com/data-acquisition>)
- [Signal Conditioning](http://www.ni.com/signalconditioning) (<http://www.ni.com/signalconditioning>)
- [Specifications Explained: NI Multifunction I/O \(MIO\) DAQ](http://www.ni.com/product-documentation/53090/en/) (<http://www.ni.com/product-documentation/53090/en/>)

For more tutorials, return to the [NI Measurement Fundamentals main page](http://www.ni.com/white-paper/4523/en/) (<http://www.ni.com/white-paper/4523/en/>), <http://zone.ni.com/devzone/cda/tut/p/id/4523>

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