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Understanding Data Acquisition - Data that Matters

In February of 1473, when Nicolaus Copernicus was born, the common definition of astronomy was: "the study of how the sun, moon, stars and celestial objects revolve around the earth." Today, we know that the very definition of astronomy given in those days precluded scientists from ever understanding the true nature of our solar system and universe. In fact, more than 100 years later, when Galileo was able to prove Copernicus' theories with his new telescope, the idea that the earth revolved around the sun was considered heretical. Galileo was banished and put on house arrest for over 10 years for his observations.

Today, a surprisingly similar situation exists in the Data Acquisition (DAQ) world. By definition, Data Acquisition Systems are designed to gather and store data. However, this definition has led many plant managers and engineers to spend substantial amounts of money on systems that do just that - gather data - but are good for little else.

The true purpose of a DAQ system is not to gather data - it is to obtain Mission Critical Information.

In reality, data acquisition is not the purpose of DAQ systems - obtaining Mission Critical Information (MCI), is. Industrial plants, manufacturers, and producers do not need to simply know the temperature, pressure, or production volume of any given piece of equipment in their plant; they need to know what that data means and how it relates to their operations. In other words, the data, in-and-of-itself, is useless, unless it meets these three criteria:

Data obtained through a DAQ must meet 3 criteria: It must be accurate, clean, and useful.

1. **Accurate** - When information is initially recorded at the source, how, exactly, does the reading match the real-life environment it is recording? As we will see in a minute, accuracy is determined almost wholly by the transducers in your DAQ system and their physical placement.

2. **Clean -** Most industrial environments are harsh and noisy, offering extensive opportunities for data transmissions to pick up interference of one type or another. This interference causes data corruption, making your end reading "dirty." Keeping your data clean is the job that your transmission, filtering and sampling systems, and DAQ hardware must fulfill.

3. **Useful -** As was previously mentioned, data delivered by a DAQ system is meaningless until it is converted into Mission Critical Information. Analyzing, converting, and storing this information is accomplished by your software drivers, application software, data storage systems, and, of course,

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International Headquarters: 707 Dayton Road - PO Box 1040 - Ottawa, IL 61350 USA
815-433-5100 Fax 433-5104 *www.bb-elec.com* *orders@bb-elec.com* *support@bb-elec.com*
European Headquarters: Westlink Commercial Park - Oranmore, Co. Galway, Ireland
+353 91 792444 Fax +353 91 792445 *www.bb-europe.com* *orders@bb-elec.com* *support@bb-europe.com*

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your end users, who will ultimately be responsible for using the DAQ system to extract Mission Critical Information.

Once these three criteria have been met, you are in a position to make your DAQ system a cost-effective, productive and profitable component of your operations. Without these three components you simply have a data acquisition system that does little more than gather and store data - and often faulty data at best.

DAQ System: Component Overview

In order to achieve a real MCI system, it is important to understand, and then effectively utilize each hardware and software component within that system. We'll briefly discuss these components of your system:

1. Transducers
2. Signal & Transmission
3. Signal Conditioners
4. Analog to Digital Converters (ADC) & DAQ Hardware
5. Software Drivers & Applications

The following is an overview of each of those components.

1. Transducers

All data acquisition systems begin with the physical phenomenon you want to have measured. Here are some examples of typical physical phenomena found within industrial environments:

Transducers - or sensors - are positioned at the data origination point. They are responsible for reading physical phenomena and converting it into a signal.

- Pressure
- Force
- Light
- Fluid/Volume
- Temperature
- Sound
- Acidity/Alkalinity (pH)

Transducers - or sensors as they are more commonly known - are the instruments that take these physical phenomena and convert them into a distinct, measurable electronic signal. There are many different kinds of transducers, each type being specifically equipped to accurately measure a certain type of physical phenomenon. Selecting the appropriate transducers for the phenomenon you are

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measuring is the first, and possibly the most essential step in creating a true MCI system, as opposed to a DAQ system.

Here is a basic chart that will help you identify the types of transducers you can choose from:

Transducer/Sensor Type	Physical Phenomenon to Be Measured
Strain Gauges Piezoelectric Transducers Hydraulic & Pneumatic Load Cell Magneto-Electric Force Sensors	Force & Pressure
Optometer Photo Sensors Vacuum Tubes	Light
Liquid Level Switch Rotational Flowmeters Pressure Switch	Fluid & Volume
Thermistors Thermocouples Resistive Temperature Devices	Temperature
Microphone Piezoelectric Transducers	Sound
pH Electrodes	Acidity/Alkalinity (pH)

Transducer types are extremely specialized toward the type of physical phenomena that you need to measure. Selecting the right transducer is the first step in achieving a real MCI system.

Installation, configuration, calibration and set of your transducers can represent one of the most time-consuming and challenging aspects of creating a true MCI System. While the intent of this paper is not to provide an in depth overview of these aspects of your DAQ system, it should be noted that over the past few years NIST (National Institution of Standards and Technologies) has been aggressively working on a set of communication standards for transducers (IEEE 1451). These standards allow you to quickly install, query, locate and monitor a wide variety of transducers within your system and on your network. More information about these standards and supported transducers can be found at: http://ieee1451.nist.gov/.

2. Signal & Transmission

NIST is constantly refining transducer communication and calibration standards. These standards will assist in quickly and efficiently deploying, managing, and adjusting a DAQ system.

Once the transducer has registered a physical phenomenon and converted it into an electronic signal, it must be transmitted from its originating location, to the computer where it will get converted into usable information.

There are two major aspects of signal and transmission that should be considered:

1. Signal Type
2. Transmission Medium & Configurations

First, signal type. There are two types of signal types: Analog and Digital.

Analog signals can represent any value with respect to time, and therefore are able to communicate the most accurate data. Analog signal types include pressure, sounds, temperature, and volume. Analog signals are three dimensional in nature because they are made up of three major elements, which are: level, shape, and frequency. Each of these aspects can be combined in various ways to produce highly accurate information. However, as we'll discuss in a moment, this also means that the number of ways that an analog signal can be disrupted and/or corrupted are also much higher than a digital signal.

Two types of signal: Analog and digital. Analog is most commonly used in industrial environments because of its "3-D" nature - or its ability to simultaneously register multiple aspects of a physical phenomenon.

Digital signals are essentially two dimensional, containing only two major elements, which are state and rate. Thus, digital signals are excellent for monitoring a switch that is open or closed (the state aspect of the signal), or how fast a motor is rotating (the rate aspect). Digital signals are less flexible at the transducer level in the variety of data they can transmit, but are also less vulnerable to disturbances from harsh environments.

Second, transmission medium and configurations.

When selecting the medium for transmitting your signal, you have two basic choices: wireless or wired. Both have a number of environmental hazards, costs, and factors to deal with. Our whitepaper titled, "Industrial Wireless: Solving Wiring Issues by Unplugging" goes into detail about your options in this arena and is an excellent resource on the topic (Full text can be seen here: Industrial Wireless: Solving Wiring Issues by Unplugging).

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815-433-5100 Fax 433-5104 *www.bb-elec.com* *orders@bb-elec.com* *support@bb-elec.com*
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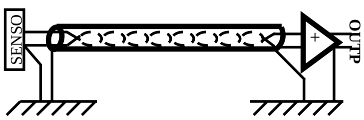
Increasingly, using wireless transmission systems are the best choice for industrial environments. Generally, wireless systems are more flexible, stable, adjustable, and more cost efficient.

In short, wireless networks afford a substantial amount of flexibility, convenience, distance, and speed, but great care must be taken in selecting your hardware to avoid issues with signal echo, channel sharing and congested radio environments.

Wired environments are stable, less prone to pick up interference, and, at short distances, can be less costly than wireless networks. However, they have significant distance restrictions, which can quickly escalate costs inside distance intense environments, suffer from long-term degeneration, and are burdensome to reconfigure. It should be noted that in almost all cases, signals should be transmitted over shielded twisted pair wiring that, ideally, would be configured with grounded and shielded connections at both ends of the system. This type of configuration is referred to as differential-input channel or balanced input channel and it drastically reduces industrial interference and noise levels that tend to corrupt your data.

3. Signal Conditioners



Grounded sensor, using shielded twisted pair, with shield connection on both ends is optimal for reducing noise and EMI in wired transmission systems.

Industrial strength signals are often too weak, too strong, too high in voltage, or too erratic to be used by most DAQ hardware components. This means that while your transducers have registered physical phenomena, you are still not able to convert it into Mission Critical Information. To accomplish this, the signal must be normalized and stabilized without losing any data quality.

This normalization process is accomplished through the use of signal conditioners. There are an extensive variety of signal conditioners, each specifically designed to deal with the enormous variety of signal types that you can generate. Here is a brief list of the types of functions that signal conditioners can perform:

- Multiplexing
- Amplification
- Isolation
- Sensor Excitation
- Attenuation
- High & Low Pass Filtration
- Conversion & Computation
- Linearization

When selecting your signal conditioners, be sure to consider the following options:

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Signal Conditioners stabilize and normalize the signal without compromising data quality or integrity. Conditioning is necessary to enable DAQ hardware to register and process that data within the signal.

- **Packaging** - Integrated, In-line, Modular, etc…
- **Protocol & Interface** - TCP/IP, Modbus, RS484, RS232, etc…
- **Environment Rating** - Class I, Class II, Division 1 & 2, Group A, B, C, etc…
- **I/O & Configuration** - Software configured, pin configured, I/O count, etc…
- **Signal Type** - Matching signal type with conditioner type is essential.
- **Additional Features** - Power requirements, email and notification abilities, wired or wireless, etc…

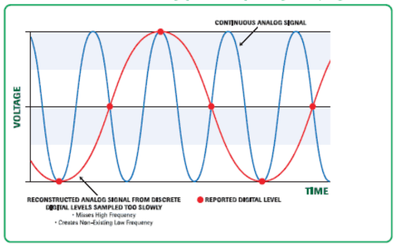
4. Analog to Digital Converter (ADC) & DAQ Hardware

Analog to Digital Converter

Analog to Digital Converters (ADC) take regular samples of analog signal and translate those data samples into digital information that DAQ software packages can understand and analyze. The essential key to success in this conversion process is securing a large enough sample to retain data integrity. The most accurate and easiest way to ensure you are getting all the data you need, is to sample at twice the rate of your highest possible frequency. For example, if a signal is coming in at 900 Hz then your sampling speed - or what is called your sampling resolution - will need to be at 1800 Hz.

ADC devices are defined by this resolution, ranging from 8-bit to 32-bit. Obviously, the higher the resolution, the higher your rate of accuracy and data integrity. But it also means that your costs will be higher. Because of this, it is essential to calculate exactly what your sampling rates will really be and balance that with budgeting needs. Further information on data sampling, including how to calculate your resolution needs, can be found in our paper, The Fine Art of Analog Signal Sampling (click here).

Nyquist Frequency (sampling too slow)



Low resolution ADC components can cause under-sampling. This will result in permanent data loss and negate the effectiveness of your DAQ system. Adequate sampling is essential.

DAQ Hardware

Simply stated, DAQ hardware is simply the interface between your computer system and all the other elements of the DAQ system that we have already discussed. The job of the DAQ hardware is to take the signal from various sources within your system and seamlessly feed those signals to your computer system for processing, analysis and storage.

DAQ hardware can be modular, portable, in-line, distributed, or integrated right into your desktop systems, depending on your needs

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and environment. Additionally, DAQ hardware can connect through USB, RS-232, RS-485, PCMCIA (for laptops), PDA's, Pocket PC's, Ethernet, Internet, Wireless (802.11 or proprietary), and PCI slots.

5. Software Drivers & Applications

Software Drivers

DAQ Hardware interfaces between your computer and all the external components of your DAQ system.

Software Drivers provide the control and interface between the DAQ Hardware and your computer system. Drivers serve two main functions:

1. **Data Traffic Flow Control** - directs communications between the computer system and DAQ hardware.

2. **Hardware Interface** - Typically some type of graphical user interface (GUI) is provided so that developers and programmers do not have to interface with the DAQ hardware at the hardware's register level.

Applications

While ADC and conditioners are at the heart of retaining data integrity, the applicant component is where you finally turn your DAQ system in to a Mission Critical Information system. The application allows you to monitor, control and analyze virtually every aspect of your data acquisition. Here you define how much data you want, how often, and from what transducers. Additionally, you determine what that data actually means, what signal levels are considered normal, and which are out of bounds and demand attention. Finally, how you instruct the application to process and store the data, inevitably defines how useful it is or is not to the success of your operation.

Consider applications that have interface tools to reduce programming time and increase system flexibility. These high-level tools will empower you to quickly acquire critical data, make changes to your overall system, and reduce programming errors.

Summary

The Application is the most essential aspect of converting your data into Mission Critical Information.

In the end analysis, data acquisition systems are really only minimally about taking readings and recording data. It is far more about securing and understanding Mission Critical Information. Because of this, each component of your DAQ system must be accurate, consistent, and efficient in carrying out its specific operations. Errors in operation at any point along the data path can

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cause data corruption and permanent loss of Mission Critical Information. In turn, this loss renders your DAQ system useless.

Like the errors perpetuated by the definition of astronomy in the 13th Century, DAQ Systems falsely suggest that the primary objective is simply obtaining data. In reality, the only objective should be to secure Mission Critical Information.

Here is a summary of each component within a DAQ system and the critical function it plays:

1. **Transducers** - Registers physical phenomena and converts it into analog (typical) or digital signal
2. **Signal & Transmission** - Contains data about the physical phenomena you are recording and securely transmits it along the data path with minimal interference or data corruption
3. **Signal Conditioners** - Stabilizes and normalizes signal while retaining data integrity
4. **Analog to Digital Converters (ADC) & DAQ Hardware** - Converts analog signal to digital data while retaining data integrity and serves as an interface between your industrial environment and computer systems
5. **Software Drivers & Applications** - Interfaces between DAQ hardware and your application, which ultimately converts data into mission critical information

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