Grant Maloy Smith

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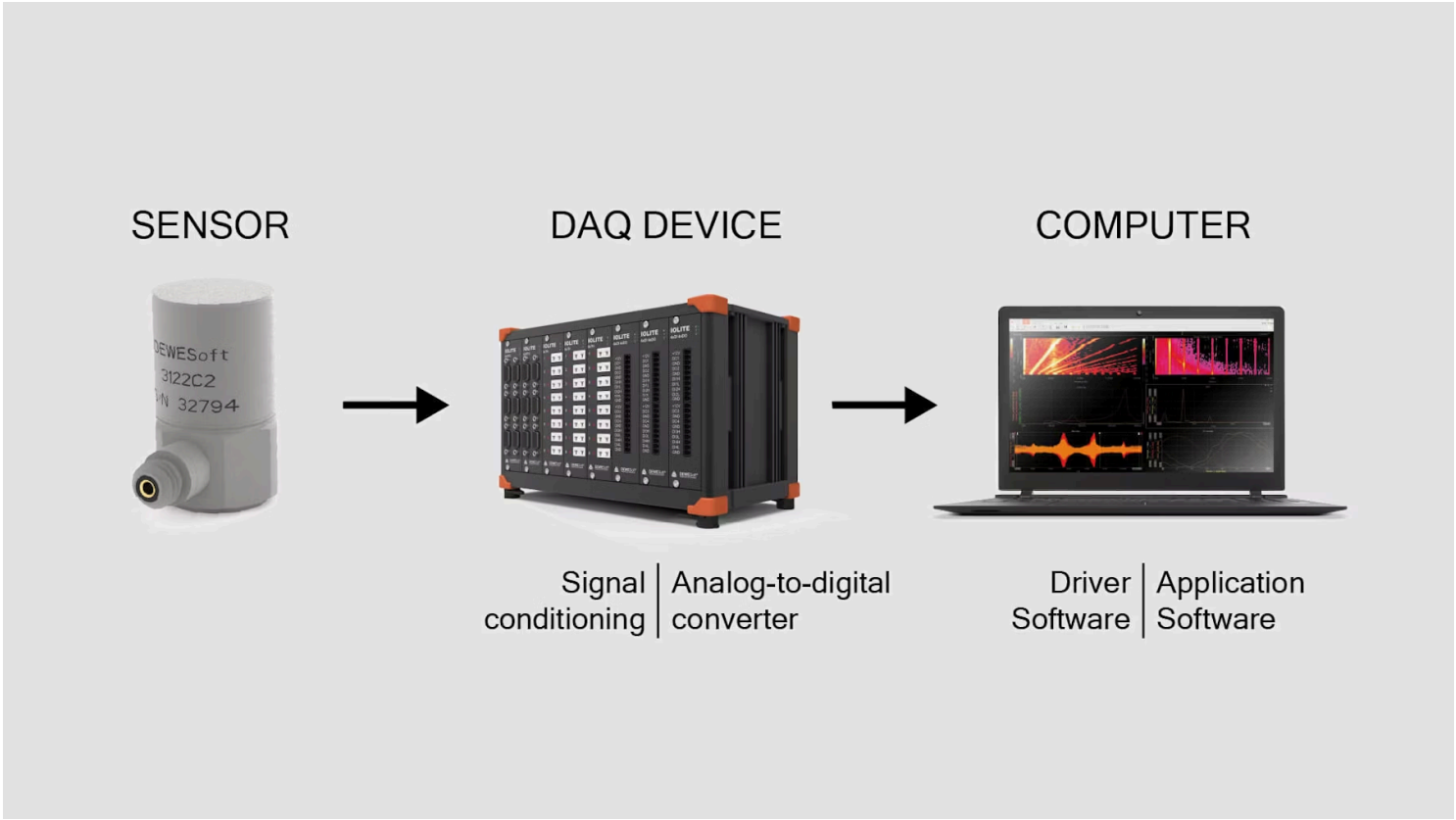
Data Acquisition (DAQ) - The Ultimate Guide [Updated 2024]

In this article we will learn everything about Data Acquisition (DAQ), describing it in enough detail that you will:

- **See** what data acquisition (DAQ) is
- **Learn** about the key data acquisition system features and capabilities
- **Understand** how data acquisition is used today, and most important why

Are you ready to get started? Let's go!



measure real-world physical phenomena and converting them into a digital form that can be manipulated by a computer and software.

Data Acquisition is generally accepted to be distinct from earlier forms of recording to tape recorders or paper charts. Unlike those methods, the signals are converted from the analog domain to the digital domain and then recorded to a digital medium such as ROM, flash media, or hard disk drives.

What is a data acquisition system?

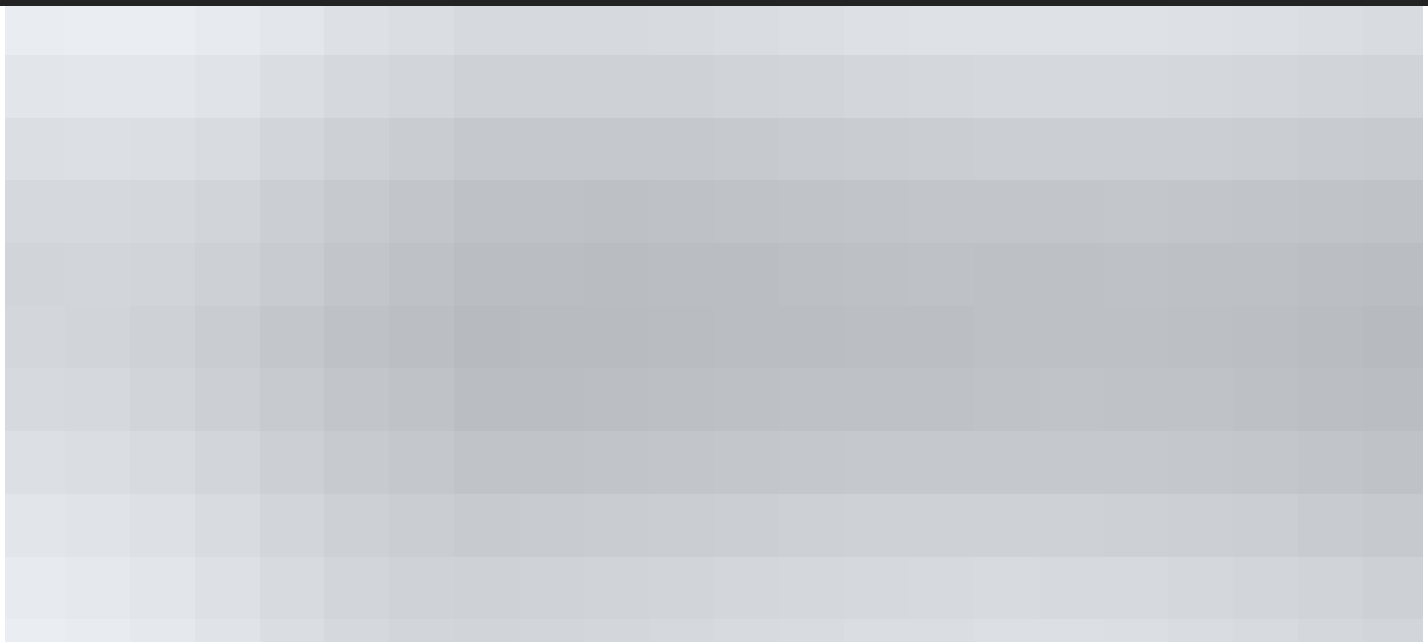
A data acquisition system is a system that includes measurement devices, sensors, a computer, and data acquisition software. A data acquisition system is used for acquiring, storing, visualizing, and processing data. This involves collecting the information required to understand electrical or physical phenomena.

There are several types of data acquisition systems. It can be a handheld device for simple temperature measurement or a big multi-thousand channel system installed in several racks and remotely operated. Jump to section types of data acquisition systems to learn more about basic types of data acquisition systems.

Components of a data acquisition system

Modern **digital data acquisition systems** consist of four essential components that form the entire measurement chain of physics phenomena:

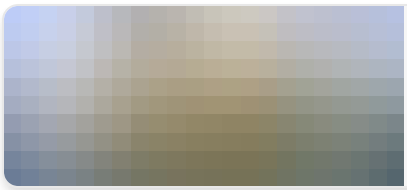
- Sensors
- Signal Conditioning
- Analog-to-Digital Converter
- Computer with DAQ software for data logging and analysis



Data acquisition system block diagram and the elements of the modern digital data acquisition system

The typical data acquisition system has multiple channels of signal conditioning circuitry which provide the interface between external sensors and the A/D conversion subsystem.

Learn more:



What Is A Sensor and What Does it Do?

Sensors ultimate guide. See what the sensors are. Learn about major sensor types. Understand the importance of sensors in the data acquisition (DAQ).

What Is Signal Conditioning or Signal Conditioner?

The complete guide to signal conditioning in data acquisition. Learn what signal conditioning is, types of signal conditioners, and the technology behind.

What Is ADC Converter (Analog-to-Digital Converter)?

The ultimate guide to ADC converters (Analog-to-Digital converters). Learn what do they do and which types are best for data acquisition applications.

- Temperature
- Voltage
- Current
- Strain and Pressure
- Shock and Vibration
- Distance and Displacement
- RPM, Angle, and Discrete Events
- Weight

Note that there are several other measures, including light and images, sound, mass, position, speed, etc. that can be measured by the data acquisition system.

The purposes of data acquisition

The primary purpose of a data acquisition system is to acquire and store the data. But they are also intended to provide real-time and post-recording visualization and analysis of the data. Furthermore, most data acquisition systems have some analytical and report generation capability built in.

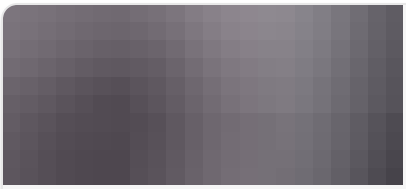
A recent innovation is the combination of data acquisition and control, where a high-quality DAQ system is connected tightly and synchronized with a real-time control system. You can read more about this topic in the related article: “Merging Data Acquisition with a Real-Time Control System”.

Engineers in different applications have various requirements, of course, but these key capabilities are present in varying proportions:

- Data recording
- Data storing
- Real-time data visualization
- Post-recording data review
- Data analysis using various mathematical and statistical calculations

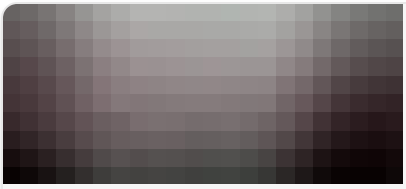
- Monitor the condition of complex machinery such as generators, motors, fans, etc.
- Monitor structural properties of buildings such as bridges, stadiums, etc.
- Monitor energy consumption and energy efficiency in the production process.
- And many other monitoring scenarios.

Learn more:



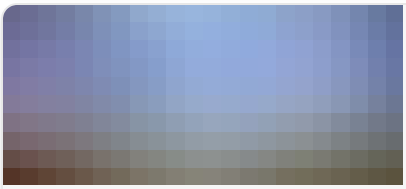
What Is Condition Monitoring and Why Is Preventing Machinery Failures Important?

This article will teach you what is condition monitoring and how it can prevent machinery failure and lower your maintenance costs.



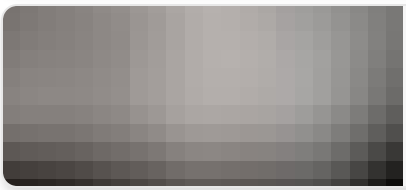
How to Perform Condition Monitoring With Dewesoft Condition Monitoring Systems

Learn how to perform condition monitoring with Dewesoft Condition Monitoring Systems and identify problems of the critical machinery at the right time.



How to Interpret the Data From Your Machine Condition Monitoring Solution?

Learn how to interpret and understand the vibration data from your condition monitoring system & protect critical machinery from failure. Start saving now.



Monitoring

Monitoring Solutions

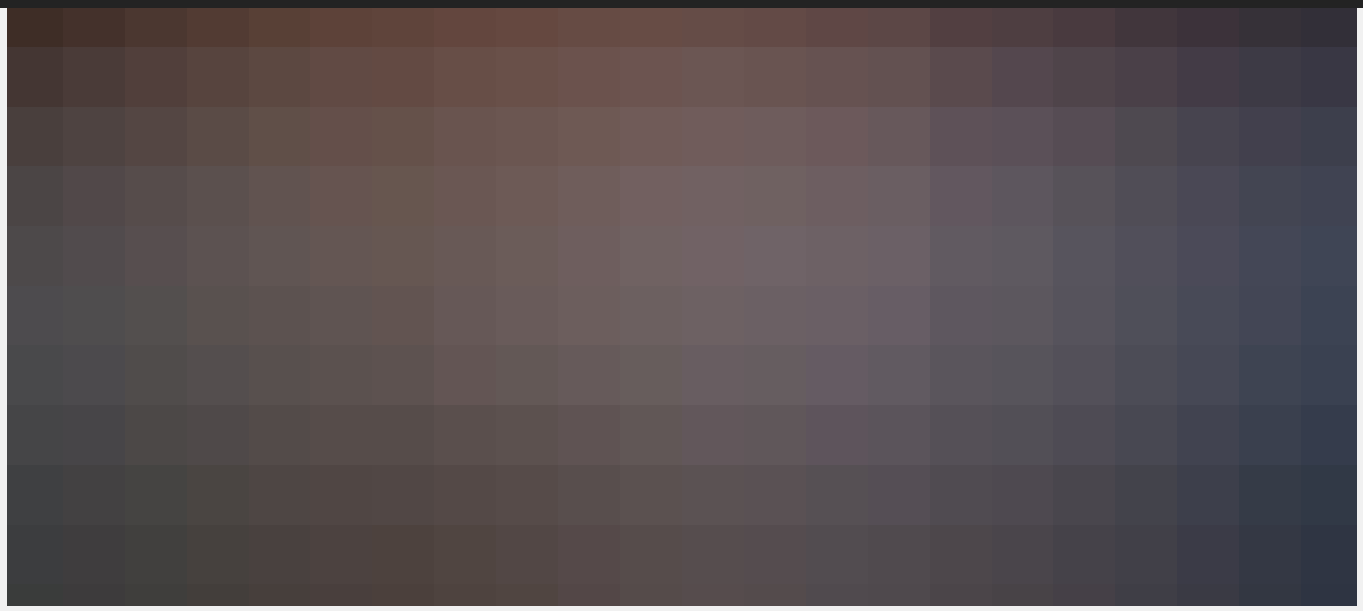
Importance of data acquisition systems

Data acquisition systems or DAQ devices are essential in the testing of products, from automobiles to medical devices - basically, any electromechanical device that people use.

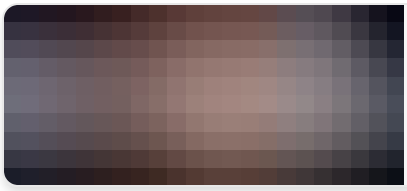
With the invention and development of data acquisition systems, which could collect data from a wide variety of sensors, these kinds of subjective opinions were replaced with objective measurements. These could easily be repeated, compared, analyzed mathematically, and visualized in many ways.

Example of a testing scenario where Dewesoft's data acquisition system is used to record, store and analyze the data during extreme weight load testing on a truck

Today, no one would consider making any kind of vehicle, large or small, aircraft, medical devices, large-scale machinery, etc without employing data acquisition to objectively measure their performance, safety, and reliability.



Learn more about Dewesoft data acquisition technology:



Dewesoft Data Acquisition Technology Explained

Find out which are the most important Dewesoft DAQ technologies and learn more about their principle of operation and how they improve the DAQ process.

Basic types of data acquisition systems

Today's data acquisition systems come in many forms and flavors:

- Handheld data acquisition systems
- Portable data acquisition systems (with a built-in computer, storage, and display)
- Modular data acquisition systems
- Rack-mountable data acquisition system
- Etc.

There are many data acquisition systems to choose from that suit certain applications. To learn about different types of data acquisition systems please check the following article:

The measurement process

Data acquisition is the process of converting real-world signals to the digital domain for display, storage, and analysis. Because physical phenomena exist in the analog domain, i.e., the physical world that we live in, they must be first measured there and then converted to the digital domain.

This process is done using a variety of sensors and signal-conditioning circuitry. The outputs are sampled by analog-to-digital converters (ADCs) and then written in a time-based stream to a digital memory media, as mentioned above. We usually call such systems the measurement systems.

A complete scheme of an analog data acquisition system

Let’s look at each of these elements in the chain in more detail.

Sensors or transducers

The measurement of a physical phenomenon, such as the temperature, the level of a sound source, or the vibration occurring from constant motion, begins with a sensor. A sensor is also called a

type of sensor used for measuring temperature. Using colored mercury in a closed tube, relies on the fact that this chemical has a consistent and linear reaction to changes in temperature. By marking the tube with temperature values, we can look at the thermometer and see what the temperature is with limited precision.

The classical thermometer is used to measure temperature for centuries

Of course, there is no analog output other than the visual one. This kind of primitive thermometer, while useful in the oven, or outside the kitchen window, is not particularly useful for data acquisition applications.

So other types of sensors have been invented to measure temperatures, such as **thermocouples, thermistors, RTDs (Resistance Temperature Detectors),** and even infrared temperature detectors. Millions of these sensors are at work every day in all manner of applications, from the engine temperature shown on our automobile dashboard, to the temperatures measured in pharmaceutical manufacturing. Virtually every industry utilizes temperature measurement in some way.

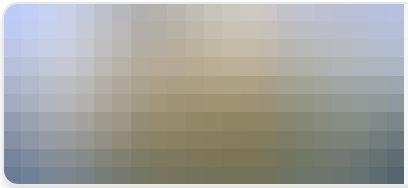
Temperature sensor types

Of course, there are many other **types of sensors** that have been invented to measure another physical phenomenon:

- **Load cells:** for measuring weight and load
- **LVDT sensors:** LVDTs are used to measure displacement in distance
- **Accelerometers:** measuring vibration and shock
- **Microphones:** for measuring sound,
- **Strain gauges:** to measure strain on an object, e.g. measure force, pressure, tension, weight, etc.,
- **Current transducers:** for measuring AC or DC current,
- and countless more.

Depending on the type of sensor, its electrical output can be a voltage, current, resistance, or another electrical attribute that varies over time. The output of these analog sensors is typically connected to the input of a signal conditioner, which we will discuss in the next section.

Learn more about sensors:



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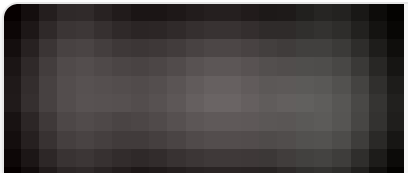
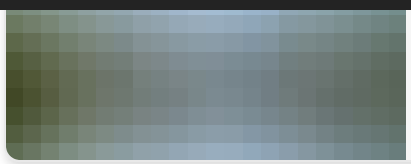
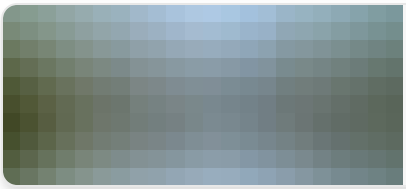


What Is a Strain Gauge Sensor and How Does It Work?



How to Measure Weight With Load Cell Sensors

See how load cell sensors work. Learn how weight measurements are made in science and industry. Understand how you can incorporate them into your testing.



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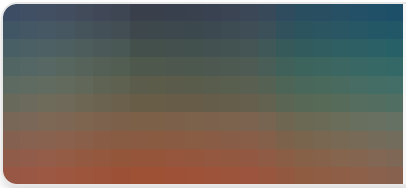
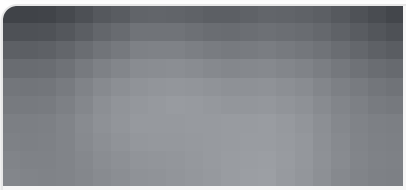


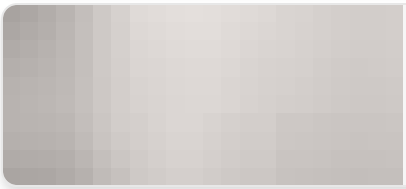
What Is a Thermocouple Sensor and How Does It Work?

In this article, you will learn what is a thermocouple, which are the basic types available, and how the temperature is measured with these sensors today.



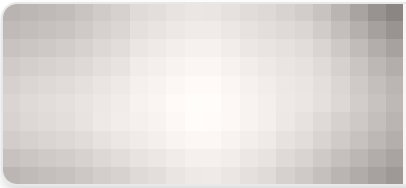
How To Measure Temperature with RTD Sensors [PT100, PT200, PT1000, ...]

Learn about RTD sensors (Resistance Thermometer Detectors), types of RTD sensors, how they work, and how to measure temperature with Dewesoft DAQ systems.



Voltage Measurement in Data Acquisition Applications

In this article, you'll learn what voltage measurement is, which voltage sensors and transducers are available today, and the basics of voltage measurement.



How To Measure Current Using Current Transducer

What is electrical current and how is it measured? Find out in the article and learn the basics of exact current measurements and applications via sensors.

Signal conditioners

Signal conditioners are in the business of taking the output from analog sensors and preparing them to be sampled digitally.

If we continue the example of the thermocouple. The signal conditioning circuitry needs to linearize the output from the sensor as well as provide isolation, and amplification to bring the very small voltage up to a nominal level for digitizing.

From analog signal sources to digitalized data ready for processing by computer and software

Each signal conditioning circuitry is designed by the manufacturer to perform the elemental normalizing of the sensor output to ensure its linearity and fidelity to the source phenomena, and prepare it for digitizing. And since every sensor type is different, the signal conditioners must conform perfectly to them.

Learn more about signal conditioning:

What Is Signal Conditioning or Signal Conditioner?

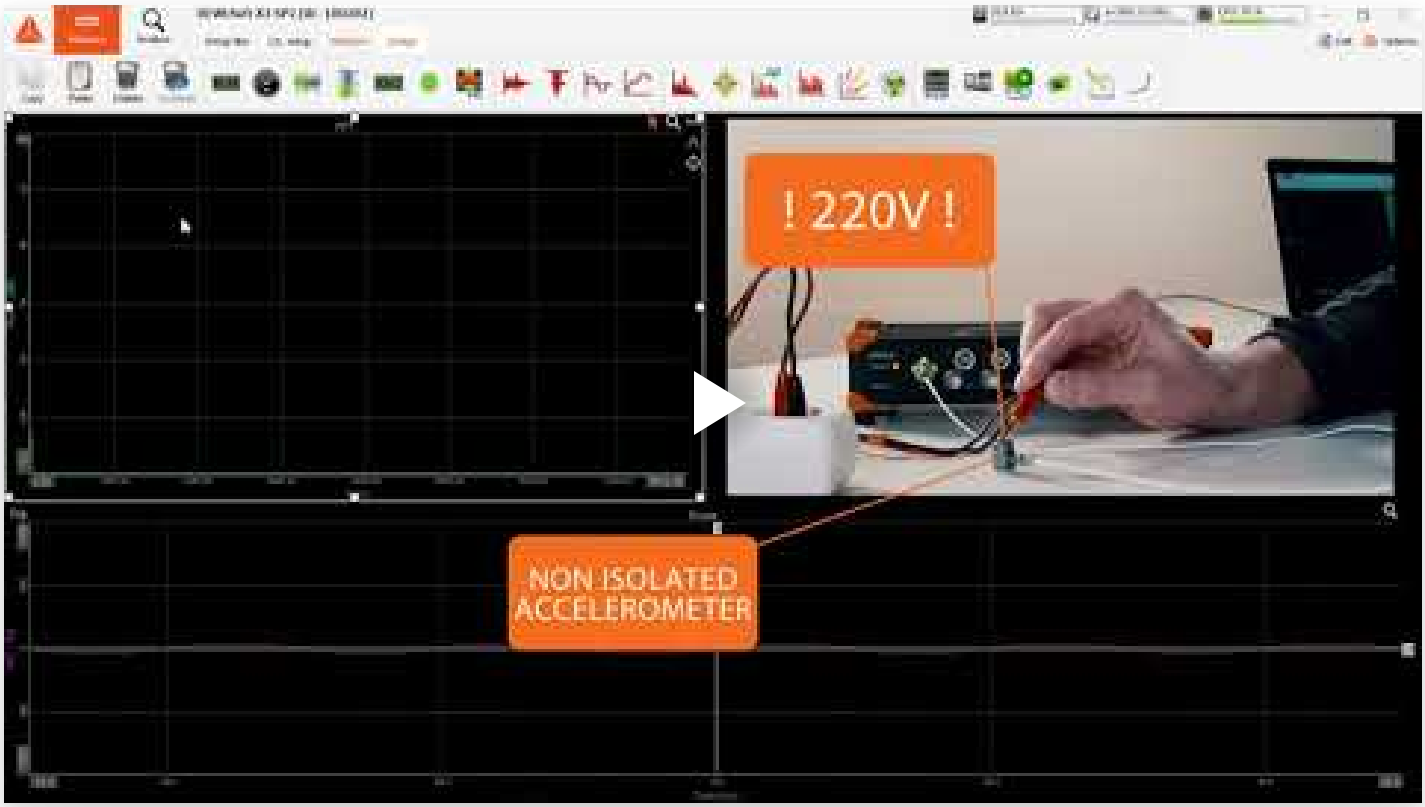
The complete guide to signal conditioning in data acquisition. Learn what signal conditioning is, types of signal conditioners, and the technology behind.

Isolation barriers (galvanic isolation)

Sometimes also referred to as galvanic isolation, electrical isolation is the separation of a circuit from other sources of electrical potential. This is especially important with measuring systems because most signals exist at relatively low levels, and external electrical potentials can influence the signal quality greatly, resulting in wrong readings. Interfering potentials can be both AC and DC in nature.

For example, when a sensor is placed directly on an article under test, (e.g. a power supply) which has potential above ground (i.e., not at 0V), this can impose a DC offset on the signal of hundreds of volts. Electrical interference or noise can also take the form of AC signals created by other electrical

This is why the best data acquisition systems have isolated inputs - to preserve the integrity of the signal chain and ensure that what the sensor outputs is truly what has been read. There are several kinds of isolation techniques employed today.



Video explaining high galvanic isolation on Dewesoft data acquisition systems

Learn more about galvanic isolation:

The Importance of Isolation in Data Acquisition Systems

Electrical isolation is a separation of a circuit from other sources of electrical potential. Learn about importance of galvanic isolation in DAQ systems.

When and Why to Use Isolated Amplifiers?

Learn why the usage of isolated amplifiers is highly recommended, in order to ensure reliable measurements, and protect your instrument from damage.

Filtering

system and the object under test. Therefore, the best signal conditioning systems provide selectable filtering that the engineer can use in order to remove these interferences and make better measurements.

In this scheme, a noise analog signal is passed through a low pass filter to filter unwanted frequencies

Filters are normally expressed in terms of the band that they operate upon. There are four basic types of signal filters:

- **Low-pass filter:** this filter reduces or "rolls off" starting at a given frequency and those above it.
- **High-pass filter:** does the opposite and allows frequencies to pass which are above a given frequency.
- **Band-pass and band-reject filters:** either pass or stop (reject) frequencies between two given values.

Basic filter types

Some filtering, such as **anti-aliasing filtering**, can only be done in the analog domain. This is because once a false signal caused by under-sampling has been digitized, there is no way to know what the real signal looked like anymore. However, nearly all other filtering can be done in the digital domain, i.e., in software, after the signal has been digitized.

Filters are also defined by how many poles they have. The more poles, the steeper the roll-off they are capable of performing on the signal. This roll-off or slope simply means how many decibels of the signal can be rolled off per octave. The specification of the filter in question will typically give the maximum roll-off in dB/Q.

Dewesoft DAQ hardware typically provides low-pass filtering as required by the types of signals being measured. Some conditioners additionally provide high-pass filtering, for example, CHARGE signal amplifiers. Removing unwanted low-frequency elements is especially critical if the measured signal will be integrated or double-integrated, as unwanted elements would badly distort the derived speed or displacement values.

You will also hear of filter types such as **Bessel**, **Butterworth**, **Elliptic**, and **Chebyshev** to name just a few. Because all filters impose distortions onto the signal itself due to their very nature, engineers over the years have developed their own filtering types in order to provide the best possible results for their specific purposes.

FILTER TYPE	ROLL-OFF STEEPNESS	RIPPLE OR DISTORTION	OTHER FACTORS
Butterworth	Good	No ripple, but square waves cause distortion (hysteresis)	Moderate phase distortion
Chebyshev	Steeper	Ripples in the pass-band	Poor transient response

Elliptic	Steepest	Ripples in the pass-band	Non-linear phase response

You can see that there are trade-offs among these filter types. Therefore it is up to the engineer to choose the best filter type for their application.

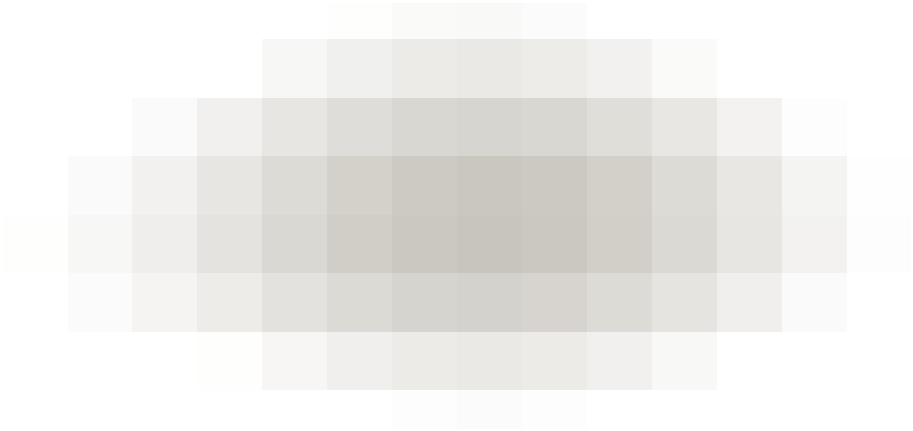
DewesoftX DAQ software provides a broad palette of user-selectable filtering options, including all of the ones mentioned above and more. It is interesting to note that software filters can be applied after measurement - and even removed or modified after measurement. This provides the engineer with many tools by which to analyze their data non-destructively.

Filtering setup inside DewesoftX data acquisition software

raw, unfiltered data and simultaneously allows the engineer to apply filters as needed, creating a different data set for analytical or presentation purposes.

Analog-to-digital converters (ADCs or AD converters)

The output of most physical measurement signal conditions is an analog signal. It is necessary to convert this signal to a series of high-speed digital values so that it can be displayed and stored by the data acquisition system. As such, an A/D card or A/D subsystem is used to convert this signal.



AD converter scheme - converts the analog signal into digital domain data

There are a variety of ADC types, including both multiplexed and single converters per channel. In a multiplexed ADC system, a single analog-to-digital converter is used to convert multiple signals from the analog to the digital domain. This is done by multiplexing the analog signals one at a time into the ADC.

This is a lower-cost approach compared to having an ADC chip per channel. But on the other hand, it is not possible to precisely align the signals on the time axis, because only one signal can ever be converted at a time. Therefore, there is always a time skew between channels.

In the early days of data acquisition, 8-bit ADCs were common. As of this writing, 24-bit ADCs are standard among most data acquisition systems designed to make dynamic measurements, and 16-bit ADCs are commonly considered the bare minimum resolution for signals in general.

The rate at which the signals are converted is called the **sample rate**. Certain applications, such as most temperature measurements, do not require a high rate since the measurements do not change very rapidly. However, AC voltages and currents, shock and vibration, and many other measurands

ADC Sampling rate

On the Y or vertical axis, ADCs are available with various resolutions. The most common today are 16-bit and 24-bit. An ADC with a 16-bit resolution can theoretically digitize an incoming signal with a resolution of one part in **`65,535`** (**`2^16 = 65,536`**).

This number is actually reduced by noise and quantization error among other factors, but it provides a good starting point for comparison. Because each bit of resolution effectively doubles the quantization resolution, systems with 24-bit ADCs provide **`2^24 = 16,777,216`**. Thus, an incoming one-volt signal can be divided into more than 16 million steps on the Y-axis.

ADCs which offer high sample rates and high amplitude axis resolution are optimal for dynamic signal analysis such as shock and vibration. Low sample rates and high amplitude axis resolution are optimal for thermocouples and other measurands which have a wide amplitude range but which do not change state rapidly.

changing signal.

If the sampling is not fine enough, the retrieved signal can be very different from the real one. Image courtesy of WikiCommons

Once converted to digital, our signals (aka measurands) are processed by the computer subsystem in several ways. First and foremost they can be displayed to the test operator on the system's screen for visual inspection and review. Most DAQ systems show the data in several popular formats, including a time-history aka "strip chart" (Y/T) display, as well as a numerical display. But other display types are available from many systems on the market today, including bar graphs, X-Y graphs, and more.

Learn more about A/D converters:

What Is ADC Converter (Analog-to-Digital Converter)?

The ultimate guide to ADC converters (Analog-to-Digital converters). Learn what do they do and which types are best for data acquisition applications.

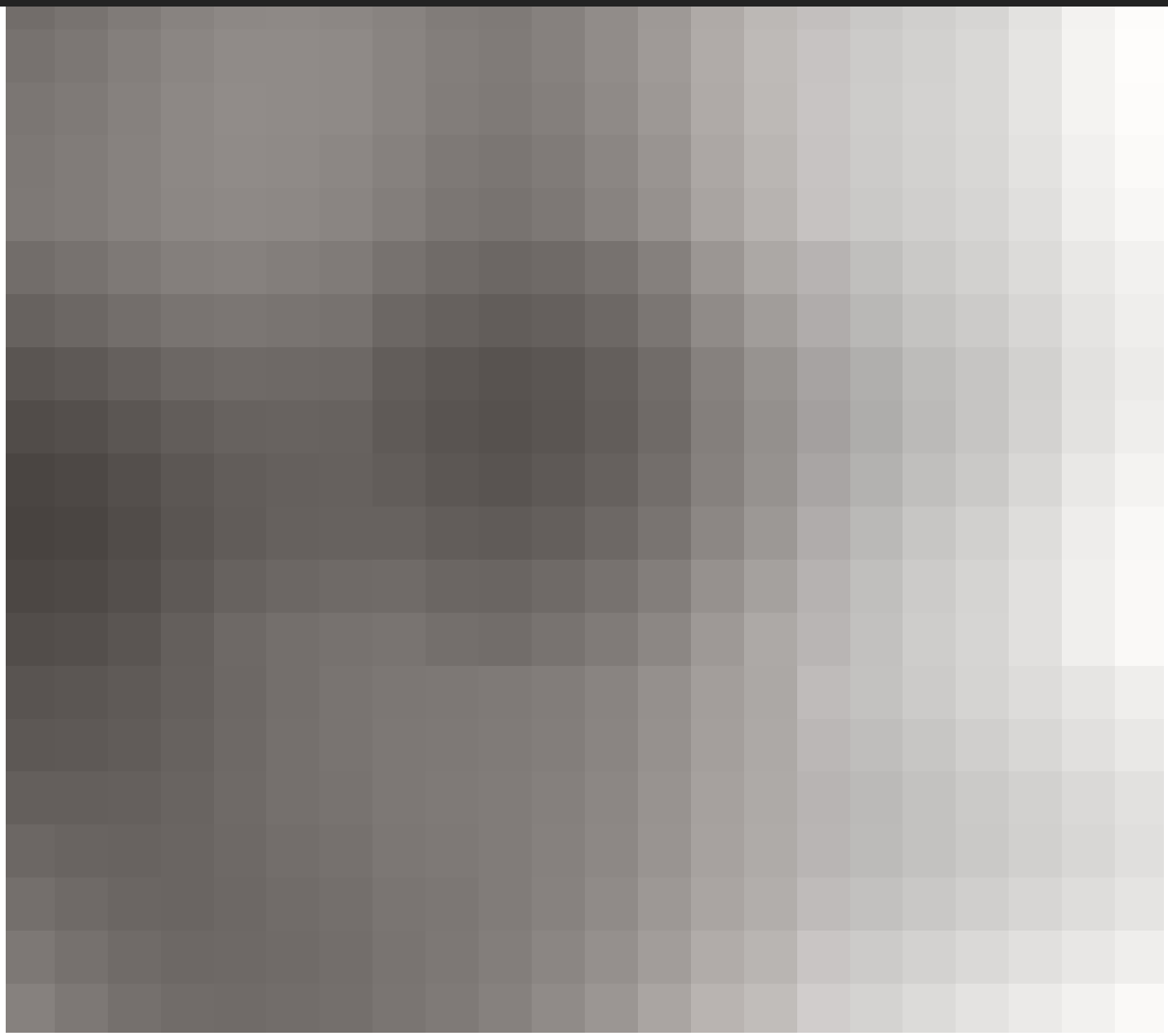
Types of ADC Converters [Updated 2024]

In this article, you will learn about the different types of A/D converters used in data acquisition systems and the basic technology of each type of ADC.

Data storage

Most DAQ systems allow the data to be exported to different file formats for analysis using third-party software tools. Common data formats include CSV (Comma Separated Values), UNV (Universal File Format), and more.

DewesoftX data acquisition software which is included for free with our modular data acquisition systems are able to export data to both formats plus many others. See the complete list of supported file export formats.



Removable SSD data storage on our rugged SBOX processing computer and data loggers

Data visualisation and display

One of the most critical functions of any DAQ system is the ability to visualize the data in real-time during data storage. Systems typically employ an integrated or separate flat-screen display, which can be configured in a variety of visual formats.

Waveform data can almost always be displayed as Y/T waveforms against a graph or grid, and in numeric form. But other graphical conventions can be employed in addition, such as bar graph

built-in graphical widgets in an easy manner. DewesoftX software offers several high-quality built-in visual instruments:

- **Recorders:** horizontal, vertical, and XY recorder
- **Oscilloscope:** scope, scope 3D, vectorscope
- **FFT:** FFT, 3D FFT, Harmonic FFT, and Octave
- **Meters:** digital, analog, horizontal/vertical bar meters
- **Graphs:** 2D, 3D graph, Octave, Orbit, Campbell plot
- **Video:** standard video display and thermal video display with temperature indicators
- **GPS:** positioning display with interactive Open Street Map layering support
- **Control:** button, switch, knob, slider, user input
- **Combustion analysis:** P-V diagram and combustion scope
- **Rotor balancer:** for field balancing
- **Automotive:** 3D polygon for displaying moving objects
- **Aerospace:** altitude or artificial horizon indicator
- **DSA/NVH:** Modal circle
- **Other:** 2D/3D table, image, text, line, overload indicator, indicator lamp, note

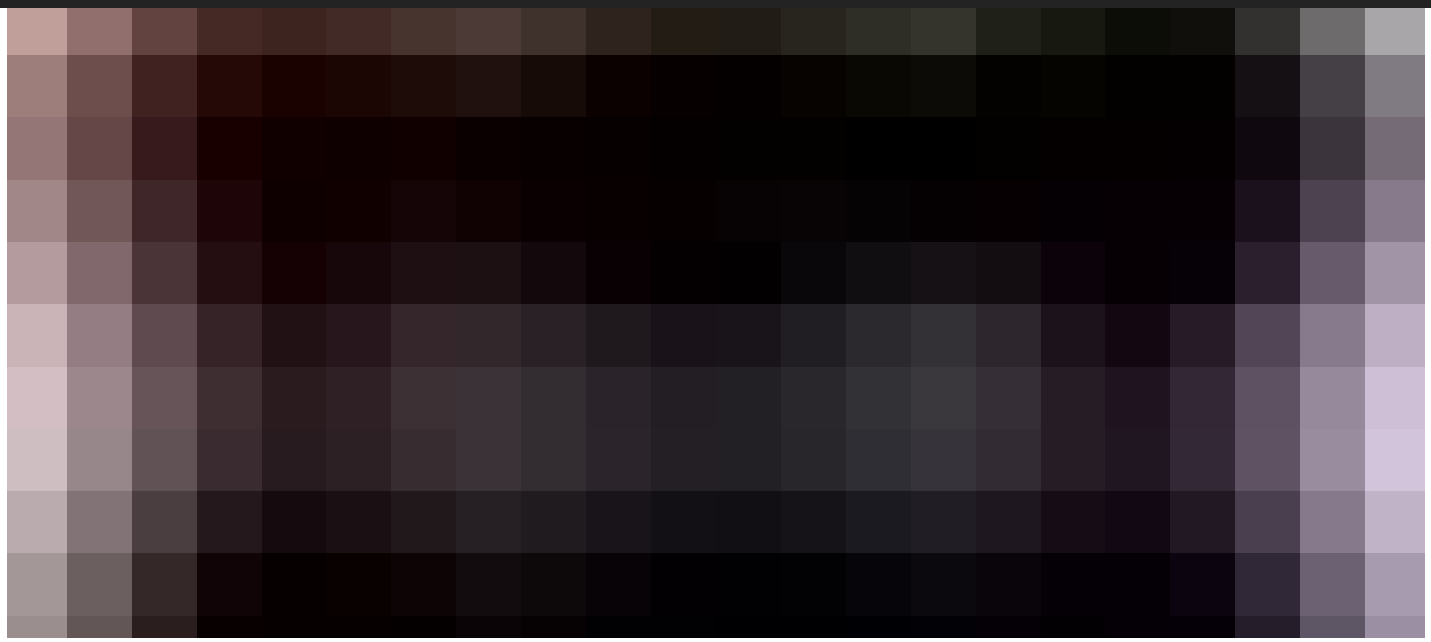
All visual instrument offers different customization options with real-time visual feedback.

Typical display from a DewesoftX DAQ software running on any Dewesoft's data acquisition system, showing measured data in a variety of user-selectable graphs and visual widgets

Data analysis

Data acquisition systems provide an important visual reference to the state of the test in real time. But after it has been stored in the DAQ system, the data can also be analyzed using tools either built into the DAQ system or third-party data analysis software.

As mentioned earlier, nearly every DAQ system on the market today has several built-in data export filters that convert the system's proprietary data format to third-party data formats for offline analysis.



Los sistemas de adquisición de datos Dewesoft proporcionan una amplia gama de funciones de análisis de datos dentro del software de adquisición de datos DewesoftDewesoft data acquisition systems provide a wide array of data analysis features inside Dewesoft X data acquisition software

Data acquisition system price

Data acquisition systems are sold by a variety of companies and are available with a broad range of capabilities and specifications, thus the prices can vary significantly. It is useful to provide general pricing for these various levels of DAQ systems, using the price-per-channel model. Estimated prices are given in USD (US dollars):

- **Low-end DAQ systems** typically range from $200 - 500 per channel.
- **Mid-range DAQ systems** typically range from $500-1000 per channel.
- **High-end DAQ systems** typically range from $1000-2000 per channel.

Do-it-yourself DAQ systems are impossible to estimate because they cover a wide span from a few channels to a system that took 10 man-years to develop and/or which involves hundreds or even thousands of channels.

The Data Acquisition Future

The future of data acquisition is promising and continuously evolving, driven by rapid technological advancements. One such example is the open data acquisition standard called OpenDAQ. **OpenDAQ** is a joint venture of two big data acquisition vendors - Dewesoft and HBK.

OpenDAQ is an SDK and is aimed to finally standardize the data protocols used in the DAQ systems. The standard defines protocols and interfaces that data acquisition vendors can implement in their hardware and software making it easier for users to integrate different data acquisition devices into their workflow.

The OpenDAQ is currently in public beta and will be fully released later in 2024.

In summary, the future of data acquisition is bright, filled with innovation that will profoundly impact society and business operations. It will be characterized by faster, more efficient, and more ethical data collection methods, powered by advanced technologies and driven by the need for deeper, real-time insights.

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Monitoring world's longest bridge
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Emergency ventilator testing
Biogas engine testing
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ADAS Testing With Velodyne Lidar DAQ
Trampoline Jumpers
Mesh WiFi
HBV on Motorbike
Bridge Collapses Monitoring
Measuring Effects of Vibration on Buildings
Noise floor analysis

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