What is Signal Processing?

Signal processing involves converting or transforming data in a way that allows us to see things in it that are not possible via direct observation. Signal processing allows engineers and scientists to analyze, optimize, and correct signals, including scientific data, audio streams, images, and video.

In this article you will learn about signal processing with enough detail that you will:

- **Understand** what signal processing is at the top level
- **Learn** how signal processing is performed
- **See** how signal processing is applied in DAQ (data acquisition) applications

Companies spend millions of dollars every year buying test equipment so that their engineers and technicians can record test data. This investment in equipment and manpower to conduct tests is for one purpose: to understand how their products will work in the real world. This understanding can only come from capturing and analyzing high-quality, objective data.
But the data itself is only step one. To understand what the data means, we need to analyze it. Analysis has several components, including:

- **Making observations** - by recording data and then reviewing it

- **Making comparisons** - one of the fundamental elements of analysis is comparing A versus B, e.g., "how much torque does the drive shaft increase when we increase the speed from 100 to 200?" or "how does the current change with respect to voltage?"

The above methods are direct observations. We apply sensors of many kinds and then operate the machine or process while recording their responses. Then we look at the data and compare parameters during different phases of operation. But there's another data analysis tool that we can use:

Signal processing - transforming data in a way that allows us to see things that are not possible by direct observation or comparison.

- **Signal processing** (aka digital signal processing), takes several forms depending on the application. In the data acquisition (DAQ) world, we use signal processing in order to analyze measured data.

How is signal processing done?

Historically, signal processing was performed entirely in the analog domain. For example, signal filters were built using discrete components like resistors, capacitors, and inductors. This is still done, of course, but since the late 20th century, data of all types have become increasingly digitized. As a result, signal processing has necessarily transitioned from the analog to the digital domain.

Today, digital signal processing is done primarily in software. Signal processing software can run on the processor or graphics card of a desktop computer, or in a smart device. For more demanding applications it runs on dedicated DSPs (Digital Signal Processors), ASICs (Applications Specific

Integrated Circuits), or FPGAs (Field Programmable Gate Arrays), and on powerful computer mainframes.

The original DSP chips were developed in the 1960s, and used for improving RADAR and SONAR in military applications. They were later applied to geophysical applications like oil exploration, space applications like data compression, and for medical imaging applications like CAT or “C.T.” (computed tomography) and MRI (magnetic resonance imaging) human body scanning.

Today, the power of even notebook computers is far greater than the biggest mainframes from the past, and a huge array of signal processing functions can be performed both in real-time and post-processing by PC-based DAQ systems.

Many systems employ a combination of host computer processing and DSP processing to perform signal processing functions. DSP hardware is very fast and can be dedicated to common functions. For example, DSPs are used in analog-to-digital converters (ADCs) for filtering, combining digital bit streams, and more. They can handle a lot of data very quickly.

Signal processing applications

Signal processing is applied across numerous industries and applications, including:

- Audio compression and signal processing
- Data acquisition and signal processing
- Digital image and graphics processing
- Video compression and signal processing
- Speech recognition and processing
- RADAR, SONAR, and LiDAR signal processing and signal optimization
- Seismic studies and data analysis
- Geophysical applications, including oil exploration
- Data transmission, including error detection and error correction
- Economic modeling and analysis
- Medical applications, especially imagery (CAT and MRI)
- Weather forecasting
- Oceanography, including undersea acoustic performance predictions

Signal processing operates on both linear and nonlinear systems, however, most systems fall into the nonlinear camp, i.e., those whose values change over time, often in unpredictable ways, where a change in output is not linearly proportional to a change in the input.

Nonlinear signal processing can be implemented in several domains, including:

- The **Time** domain, i.e., amplitude points plotted against time
- The **Frequency** domain, i.e., frequencies plotted against their magnitudes
- **Spatio-temporal** domain, i.e., across both space and time. For example, monitoring the routes of hundreds of aircraft all around the world, or thousands of satellites orbiting the Earth