



A basic introduction to data acquisition hardware - it's application, parameters and structure

Introduction

"Data Acquisition" is the link from the 'real world' of physical variables to your computer. Actual sensory information such as sound, light, temperature, vibration etc is converted by sensors to real time signals that may be interpreted by the data acquisition hardware. A computer uses this information to record, play, graph, analyse or even actively manage operating parameters.

Data acquisition equipment finds practical application in industrial control and test/analysis applications. Typically, a control system will use a transducer to sense physical phenomena and produce electrical signals that the data acquisition module measures. For example, thermocouples, resistance temperature detectors (RTDs), thermistors, and IC sensors convert temperature into an analogue signal that an analogue-to-digital converter can measure. Other examples include strain gauges, flow transducers, and pressure transducers, which measure force, rate of flow, and pressure, respectively.

Sensors are generally local to the variable to be measured. Examples of exceptions include optical or infrared detection of temperature or movement. The signal levels may be boosted locally before being passed to the actual data acquisition hardware located in a computer. Blue Chip Technology's range of data acquisition cards is available in both ISA and PCI plug-in variants. These cards make the raw data available to the controlling or monitoring computer program.

The data transfer capabilities of your computer can significantly affect the performance of your data acquisition system, the PCI bus yields up to 132

MBytes/s theoretical data transfer capabilities. However, the ISA bus, which has enjoyed unexpected longevity, is only capable of passing along data at a rate of 16 MBps or less. It is therefore recommended that all new systems should use the PCI format. The continued availability of ISA bus based cards ensures maximum investment can be secured when using legacy equipment.

Analogue vs. Digital

Depending on your application, there are several different types of data acquisition modules available – analogue or digital, input or output, counters/timers or multifunction units combining several types in one card. generate patterns for testing, and communicate with peripheral equipment.

Analogue inputs are used to measure continuously variable elements such as temperature, pressure, vibration etc. Digital inputs are used for items having discrete levels such as switches and relays. They have only two states, high and low (or on and off). Digital interfaces are typically used to control processes, generate patterns for testing, and communicate with peripheral equipment.

The key criteria to consider when choosing your digital input/output (IO) module are:

- ▶ the number of digital lines available
- ▶ the rate at which you can accept and source digital data on these lines
- ▶ the drive capability of the lines
- ▶ the environment (is it electrically noisy?)

If the digital lines are used for controlling physical on and off functions, a high data rate is usually not required because the controlled equipment cannot respond very quickly. The number of digital lines needs to match the number of processes to be controlled and the amount of current required to turn the devices on and off must be less than the available drive current from the device. Digital IO can also be used in industrial applications, to verify that a switch is open or closed and to check the voltage levels as high or low. Low-level inputs and outputs are only suitable for short cable runs in electrically quiet environments. For noisier conditions or where long cable runs are involved, always use optically isolated IO cards or relay cards.

Counters Timers

Counter/timers are used to count pulses from inputs, send out pulses to drive instruments, and generate frequency outputs for timing or to control certain types of valves and other proportionally controlled devices. The main advantage of having this capability in hardware is that it can operate at much faster rates than software driven digital outputs, and it reduces the data acquisition software overhead.

The most significant considerations of a counter/timer are the resolution and clock frequency. The resolution is governed by the number of bits the counter uses. A higher resolution simply means that the counter can count larger numbers. The clock frequency determines how coarse or fine the time steps are between successive time counts or how fast the counter can follow inputs or create outputs.

Analogue Voltage Range

Range refers to the minimum and maximum voltage levels that an analogue IO module can handle. Some signals require a large range, such as 0 to 10V, while other signals vary only a fraction of that; 0 to 10mV, for example. Most cards allow the desired input range to be selected under software control, or by setting jumpers on links on the board. The goal is to select the smallest range that will cover the maximum input expected in your application, as this will yield the greatest accuracy. Voltage inputs are also divided into unipolar and bipolar types. Unipolar ranges accept signals that are of one polarity (only positive or only negative), such as 0 to 5 Volts. Bipolar ranges accept signals that range from negative to positive values, such as ± 5 Volts.

Single-Ended or Differential Analogue Inputs

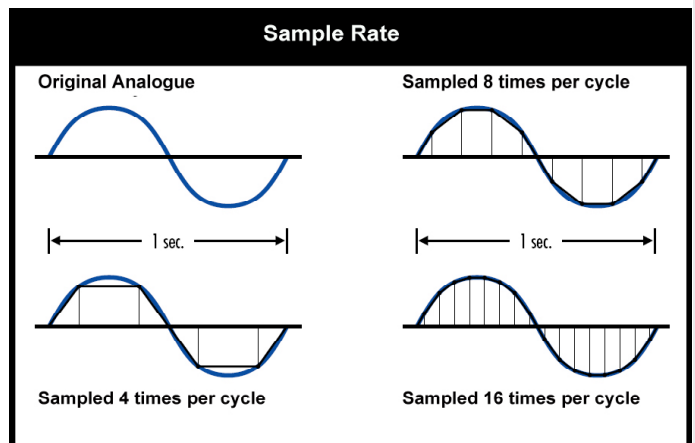
This refers to the method of terminating the inputs. Single-ended inputs are all relative to a single common reference point such as the 0V terminal. They typically have one connection per input channel, and one common connection. Differential inputs are signals that presented between two connections. They do not have a common reference and may be totally isolated from all other signals and the 0V terminal.

It is not uncommon for differential signals to have an unwanted common-mode voltage in addition to

the differential signal voltage. Differential inputs will ignore the common-mode element. Single ended inputs are best used when the input signals are high level and the leads from the signal source to the analogue input hardware are relatively short. This minimises the effects of interference or electrical noise. Differential inputs should be used for low level signals or those with long leads. Using differential inputs, noise errors are reduced because the common-mode noise picked up by the leads is cancelled out. The common mode signal appears equally on both the positive and negative inputs and can be automatically rejected. (Single-ended inputs do not have independent positive and negative inputs and therefore cannot reject common mode noise.)

Analogue Sample Rate

This parameter determines how often analogue conversions can take place. The sample rate is expressed as a frequency and is measured in Hertz. A 1000Hz sample rate means that data is collected 1,000 times per second; and a 1MHz rate samples 1,000,000 times per second. A faster sampling rate acquires more data in a given time and can therefore often form a better representation of the original signal if it is changing rapidly. Bear in mind however, a faster sampling rate can flood a system with too much data, unnecessarily filling memory. If the measured variable is only capable of changing slowly, there is nothing to be gained by measuring it frequently producing lots of identical results. Only choose a high sample rate when the input varies rapidly.

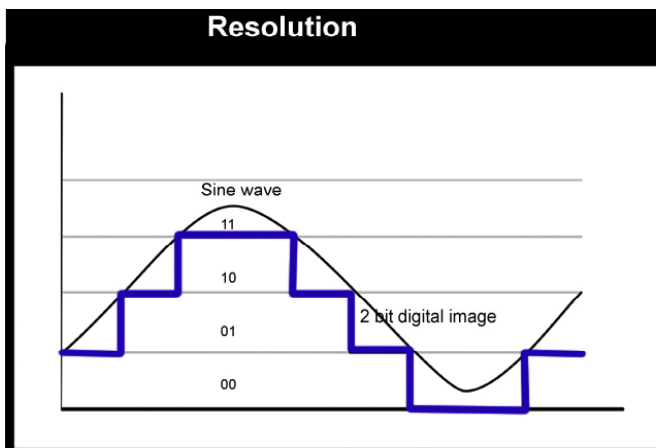


The diagram indicates what happens when you sample at different rates. As an example, take an original waveform with a frequency of 1Hz and sample it at 4Hz, 8Hz and 16Hz. Notice that the values sampled at four times per cycle contain no indication that the input waveform is sinusoidal. We could infer that the input was merely changing from a positive to a negative value and back again every half second, and the view would change if the sampling points were not those shown. You certainly couldn't reconstruct the original input waveform from the measured values. The values obtained at eight samples per cycle are little better.

Analogue Resolution

Resolution is another key performance indicator for an

analogue data acquisition board – it is a measure of the number of steps (bits) that are used to represent the maximum input value. The higher the resolution, the larger the number of divisions the range is broken into and the greater the accuracy in recording changes in voltage.



In the diagram, you can see a sine wave and its corresponding 2-bit digital image. A 2-bit number can only be arranged in four combinations – 00, 01, 10, & 11, consequently the resulting digital representation of the original sine wave is pretty poor.

However, if we can use a higher resolution (more bits) each additional bit doubles the number of possible combinations, a 16 bit converter has 65,536 possible combinations making it possible to obtain an extremely accurate digital representation of the original analogue signal.

Analogue Accuracy

Resolution is only one component in the overall accuracy of data acquisition hardware. Other factors are gain error, offset, linearity, drift, noise, and calibration.

Gain Error

Gain error can take two forms, non-linear gain and gain drift. Both occur when the gain of the amplifying section of data acquisition card is not constant. It may vary with the magnitude of the input signal (non-linear gain) or with temperature or with component ageing. Non-linear gain is due to inherent inaccuracies in the conversion hardware. Adjustment cannot remove the non-linearity but may achieve a "best-fit" to minimise the error. Gain drift can be adjusted by either software calibration or by gain adjustment potentiometers on conventional data acquisition hardware. As part of the calibration procedure, usually this can only be done on one range at a time. In order to use another range accurately the unit must be recalibrated.

Offset Error:

This is the error in the reading at zero input. The error is the same at all input levels on a given range and is corrected by software or by adjusting potentiometers on conventional data acquisition hardware.

Linearity Error:

Ideally, as you increase the level of voltage applied to a data acquisition module, the digital codes from the device should also increase linearly. Linearity error occurs when the gain error varies with different input levels. A change in the input signal from 0 to 1 Volt may show a different change in the measurement than an input signal change from 2 to 3 Volts. This is due to linearity error in the conversion hardware where the individual bits do not represent the exactly the same voltage step. Generally the linearity error cannot be removed by calibration.

Drift:

The gain, offset, and even linearity errors change as the temperature of the unit changes, and with time. In order to correct for drift errors, the unit must be recalibrated.

Noise:

Any unwanted signal that appears in the measured signal is considered to be noise. Bear in mind that the PC is a very noisy electrical environment. The faster a data acquisition device can sample, the greater the potential for noise. Even when measuring slowly changing signals, a fast device picks up a great deal of noise