PLUG-IN DATA ACQUISITION BOARDS

A Technical News Article from Boston Technology

TECHNICAL BRIEF #2

PART ONE

Introduction

In recent years the distinction between separate data acquisition (DAQ) systems and control systems has narrowed, since an increasing number of real-life systems are designed not only to acquire data, but also to act on it. This is true of a wide range of plug-in DAQ and control boards now available. Commonly used multi-purpose plug-in DAQ boards, currently on the market, typically combine all aspects of DAQ and control. This includes analog input circuitry for measuring and converting analog input voltage signals to digital format, analog output circuitry for generating analog output voltages from digital control signals, counter/timing circuitry and digital I/O interfaces. Depending on the number of analog inputs/outputs and digital inputs/outputs required for a particular application, multi-purpose boards represent the most cost effective and flexible solution for DAQ systems.

Computer plug-in DAQ and control boards often represent the lowest cost alternative for a complete DAQ and control system. As they interface directly to the host computers, I/O expansion bus they are generally compact, and also represent the fastest method of gathering data and/or changing outputs. These boards are most commonly used in applications where the computer is close to the sensors being measured or the actuators being controlled. Alternatively, they can be interfaced to remotely located transducers and actuators via signal conditioning modules known as two-wire transmitters.

Also available and widely used are plug-in boards that specialize in each of the DAQ and control functions just mentioned.

Examples of these plug-in boards are:

- Analog input (A/D) boards
- Analog output (D/A) boards
- Digital I/O boards
- Counter/Timer I/O boards

A/D Boards

Analog input (A/D) boards convert analog voltages from external signal sources into a digital format which can interpreted by the host computer. The functional diagram of a typical A/D board is shown in Figure 1 and comprises the following main components:

- Input Channel Sample and Hold Circuits (for simultaneous sampling)
- Input Multiplexer [covered here - part1]
- Input Signal Amplifier [covered here - part1]
- Sample and Hold Circuit [covered here - part1]
- A/D Converter (ADC) [on the website - part2]
- FIFO Buffer [on the website - part3]
- Timing System [on the website - part3]
- Expansion Bus Interface [on the website - part3]

Each of these components plays an important role in determining how fast and how accurately the A/D board can acquire data.

Multiplexers

A multiplexer is a device that switches one of its analog inputs (typically up to 16 single-ended inputs) to its output, the input channel selected being determined by the binary code at the input address lines of the multiplexer. The number of address lines required is determined by the number of input channels to be multiplexed. A 16-channel multiplexer would therefore require four input address lines.

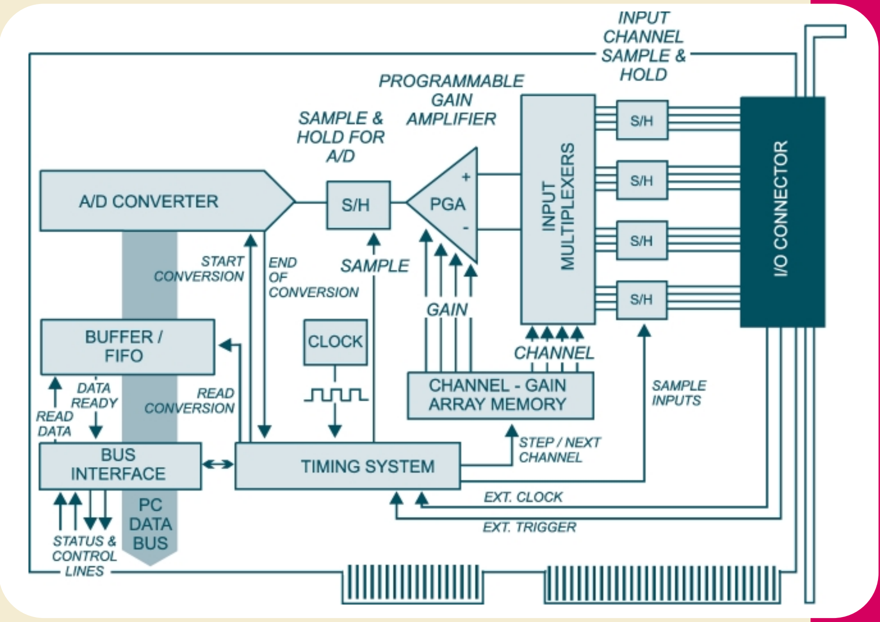

Figure 1 - Functional Diagram of a Typical A/D Board

On A/D boards, multiplexers facilitate the sampling of multiple inputs on a time multiplexed basis. The A/D converter samples one channel, switches to the next channel, samples it, switches to the next channel, samples it, and so on. This eliminates the need for a signal amplifier and an A/D converter for each input channel, thereby reducing the costs of A/D boards.

Important Parameters

Two parameters that particularly affect the rate at which the multiplexer can switch between channels, and therefore its throughput rate, are the settling time and the switching time.

- ### Settling Time

The settling time is the time the multiplexer output takes to settle to within a pre-determined error margin of the input when the input signal on the channel swings from -FS (negative full scale input voltage) to +FS (positive full scale input voltage) or from +FS to-FS.

- ### Switching Time

The switching time specifies how long the multiplexer output takes to settle to the input voltage when it is switched from one channel to another.

- ### Throughput Rate

The throughput rate is considered to be the higher of the settling time or the switching time, since it is possible the voltage on one channel can be at -FS while the voltage on the next switched channel is +FS. The throughput rate of the multiplexer is one factor that determines the total throughput of the A/D board.

Input Signal Amplifier

To achieve the greatest resolution in the measurement of an analog input signal, its amplified range should match the input range of the A/D converter. Consider a low level signal of the order of a fraction of a mV, fed directly to a 12-bit A/D converter with full scale voltage of 10 V. A loss of precision will result since the A/D converter has a resolution of only 2.44 mV.

Some form of amplification is needed. This is usually provided by a high performance instrumentation amplifier, typified by:

- Balanced differential inputs
- High input impedance
- Low input bias currents
- Low offset drift
- High common mode rejection ratio

Two types of amplifier are commonly included on A/D boards, depending on the cost and quality of the A/D board selected. Some A/D boards provide on-board amplification, where the amplifier gain is adjustable using hardware, while boards that provide Programmable Gain Amplifiers (PGAs) make it possible to select using software, different gains for different channels.

Adjustable On-Board Fixed Gain Amplifier

The gain of these amplifiers is commonly adjusted using a potentiometer or selectable on board links. A/D boards with a fixed gain amplifier should only be used where the signal levels on each of the input channels to be sampled have comparable ranges and lie within the full scale input range of the A/D converter.

Signals with greatly different signal levels will require external signal conditioning and amplification to enable them to be used on boards utilizing fixed gain amplification. A more flexible alternative is the programmable gain amplifier discussed below.

Programmable Gain Amplifier (PGA)

Programmable gain amplifiers (PGAs) make it possible to program the gain of the input amplifier using software, requiring a once-only write to an on-board register to select the gain for an individual channel.

This is especially advantageous where input signals on different channels have very different signal levels and input ranges. The amplifier gain for each channel can be set accordingly, so that the input range of the incoming signal is matched with the full scale range of the A/D converter, thus resulting in higher resolution and accuracy.

Important Signal Amplifier Parameters

Two parameters which particularly affect the accuracy and rate which the signal amplifier can amplify the input signals are amplifier drift and the settling time.

▪ Calibration and Drift

Calibration of an amplifier to eliminate offset and gain errors is only valid for the temperature at which the calibration was made. Over time, and with variations in temperature, the characteristics of the amplifier change or drift causing offset and gain errors known as ***offset drift*** and ***gain drift*** respectively. Offset drift and gain drift in parts per million per degree Centigrade (ppm/°C) specifies the sensitivity of the amplifier to changes in temperature.

Compounding the natural tendency of the amplifier characteristics to drift is the fact that the potentiometer settings of fixed gain amplifiers also tend to drift with time and temperature.

▪ Settling Time

Amplifier settling time is defined to be the time elapsed from the application of a perfect step input to the time the amplifier output settles within a pre-determined error margin of the required output value.

A characteristic of amplifiers is that the throughput decreases with increasing gain. This is because at higher gains the signal output changes by a greater amount, therefore increasing the settling time. This applies to fixed gain and programmable gain amplifiers. If the A/D converter samples the amplified input signal before the amplifier output has settled correctly, (i.e. the time between samples is less than the settling time of the signal amplifier) then an incorrect data value may be sampled.

Poor settling time is a major problem, as the level of inaccuracy varies with the gain and sampling rate and cannot be reported to the host computer.

It is usual practice that the amplifier gain, though programmable, is selected from a specified range of gain settings, thereby maintaining the amplifier within its operating range without saturation. In some high performance boards the gain is automatically adjusted depending on the level of the input signal.

To allow for the lowest possible input ranges and therefore the highest required gains, A/D boards adjust their internal timing to allow for a greater settling time for the output of the amplifier. This means that the highest allowed settling time and the reduction in throughput caused by it, is imposed for all amplifier gain settings.

More advanced A/D boards take into account the input range and amplifier gain required, thereby increasing throughput at higher signal level input ranges where lower gain settings are required.

TECHNICAL BRIEF #2

Channel-Gain Arrays

On the original A/D boards the address of the channel to be sampled was written to the multiplexer, the gain setting sent to the programmable gain amplifier (PGA) and once the signal was settled an A/D conversion was initiated. The data was subsequently read and transferred to the PC's memory. This incurred a large software overhead. Background operation using interrupts is difficult and slower than polled I/O and accurately timed samples and higher speed data transfer methods such as DMA and repeat instructions are impossible in either case.

The use of channel-gain arrays (CGA) on many A/D boards overcomes these limitations. The channel/gain array is a programmable memory buffer on the A/D board, which contains the channel address and gain setting for each input channel to be sampled. The gain of the amplifier for a particular channel is set by the internal hardware preceding the sampling of the channel, based on the gain value read from the channel/gain array. Where a single PGA is provided for all channels, the gain required for each channel is stored in a channel/gain array. If there are individual PGAs for each input channel the gains for each input amplifier are stored in a gain array. The gain of each remains the same until overwritten by the software. Channel-gain arrays vary in size from a few channel/gain pairs (one for each channel), to many thousands of pairs.

Sample and Hold Circuits

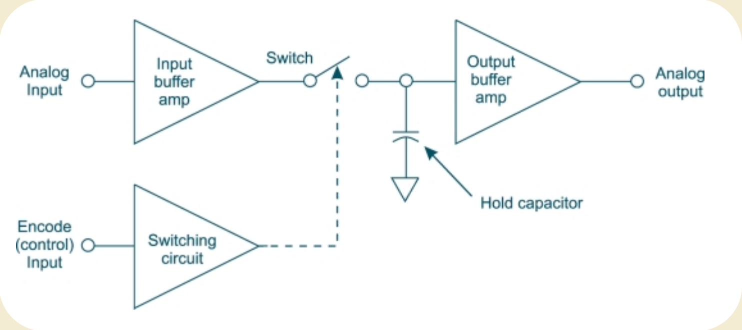

Figure 2 - Functional Diagram of a Sample-and-Hold Device

As shown in Figure 2, a sample-and-hold (S/H) device consist of an analog signal input and input buffer, analog signal output and output buffer, a charge-storing device, usually a capacitor, and a control input which controls the switching circuitry which connects the input to the output.

As its name implies, a S/H has two operating states. When in sample mode, a sample command applied to the control input closes the internal switch, thereby causing the output to track the input as closely as possible. In this mode the hold capacitor charges to the voltage level applied at the input. When a hold command is applied to the control input, the switch opens, disconnecting the output from the input. With the switch open and the high impedance of the output amplifier preventing the premature discharging of the capacitor, the hold capacitor retains the value of the input signal at the stage the hold command was applied to the control input.With the exception of some flash A/D converters, which are very fast, most A/D converters require a fixed time period during which the input signal to be convened remains constant. When used at the input to an A/D converter, a sample and hold circuit performs this function, acquiring an analog signal at the precise time its control input is made active. The A/D converter can then convert the voltage held at the output of the sample and hold, minimizing inaccuracies in the conversion due to changes in the signal during the conversion process.

Important Signal Parameters

- Hold Settling Time

The time that elapses from the occurrence of the sample command, to the point where the output has settled within a given error band of the input, is known as the acquisition time or hold settling time.

- Aperture Time

The time required to switch from the sample state, measured from the 50% point of the mode control signal, to the hold state (the time the output stops tracking the input), is known as the aperture time.

- Aperture Uncertainty

This value represents the difference between the maximum and minimum aperture times.

- Drop Rate

A practical sample and hold cannot maintain its output voltage indefinitely while in the hold mode. The rate at which it decays is known as the decay or drop rate.

- Aperture Matching

Data acquisition boards capable of performing simultaneous sampling (see Simultaneous Sampling) require sample and hold devices on each channel. The smaller the aperture time and aperture uncertainty for each of these devices, the narrower the time range over which all the simultaneous samples will be taken. For a DAQ board this is known as aperture matching. The lower the value, the more closely matched in time the simultaneous samples will be.

As a point of note, A/D boards that perform simultaneous sampling still have the sample and hold circuit that precedes the A/D converter as each channel sample still has to be multiplexed to the A/D converter. Some A/D converters have built-in sample and bold circuitry, and where this is the case, the preceding sample and hold circuit is not required.

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The discussion of Plug-in Data Acquisition Boards is continued on our website:

You may download this topic for **FREE!** **www.BostonTech.net**

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