Computer Analog Interfaces and How They Work

Analog Input/Output (I/O) (1536EB)

**National Instruments E-Series DAQ Board:**

- (4) A/D Ranges: -10 to 10V, -5 to +5, -0.5V to 0.5V, -0.05V to 0.05V
- (16) A/D channels of Single-Ended or (8) Channels Differential channels, 12 bit Analog-to-Digital Converters (ADC) with 200k sample/sec maximum rate, digital trigger
- (2) 12 bit Digital-to-Analog Converters (DAC)
- (8) digital I/O lines
- (2) independent 24 bit counter-timers with 8 MHz source clock

**National Instruments PCI-GPIB:**

Complete IEEE-488 Controller with 1.5 Mbyte/sec max transfer rate with IEEE 488.1 and 7.7 Mbyte/sec max transfer rate using HS488. DMA controller

**Digital-to-Analog Converters (D/A):**

The Digital-to-Analog (D/A) converter uses a combination of a TTL logic parallel output, a binary weighted resistor and an operational amplifier.

![Parallel Digital Output Chip (normally TTL: 0-5 volt)](image)

Using standard op-amp analysis, the output voltage is

\[ v_o = v_s \left( \frac{R}{256} \right) \sum_{n=0}^{7} \frac{b_n}{2^n} = \frac{v_s}{256} \sum_{n=0}^{7} 2^n b_n \]

where: \( v_o \) = output voltage
\( v_s \) = supply voltage
\( b_n = 0 \) or 1, the state of the \( n \)th bit

Note that this result gives “binary weighted” outputs proportional to the eight bits of the digital output chip. The accuracy of the binary-weighted resistors determines the D/A accuracy.
Analog-to-Digital Converters (A/D):

The central element in a A/D converter is a D/A converter. As shown below, the D/A converter used determines resolution and scaling of the A/D conversion process.

The Multiplexer switches one input channel to the Sample and Hold that holds a constant value during the conversion process. The Amp amplifies the analog level to fit the analog conversion range and provides an analog voltage to the Compare element. The Compare element compares this analog level with the output of the D/A Converter and provides a Boolean High or Low signal to the converter's Digital Logic. In response to this High/Low signal, the Digital Logic changes its "n" Parallel Digital Bit output to the D/A circuit to best match the analog input to the Compare. The specific algorithm used by the Digital Logic determines the type of A/D converter.

There are two basic types of A/D converters in common laboratory use.

1. The Tracking A/D Converter samples at high rates (1-10 MHz.) and at each sample increments or decrements the "n" Parallel Digital Bits so as to change the D/A output at small increments and track a changing analog input. In this way, tracking A/D Converters achieve high sample rates but have difficulty following signals which change discontinuously such as those resulting from a change in the channel selected by the Multiplexer.

2. The Successive Approximation A/D Converter samples more slowly (<250 kHz.) and develops a new conversion at each sampling time. It successively sets each bit from the most significant to the least significant, testing the D/A output at each step. For "N" bits, "N" tests are required to complete the conversion. Although slower than the tracking A/D, the successive approximation A/D can deal with discontinuous inputs from the multiplexer and maintains a constant sampling interval. Because the successive approximation A/D converter works well with switched inputs and allows multi-channel sampling at moderate
rates, it is the most common (cost effective) A/D for laboratory use in computer data acquisition systems